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THE BOOK OF INVENTION

BY

T. C. BRIDGES

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JOINT AUTHOR OF
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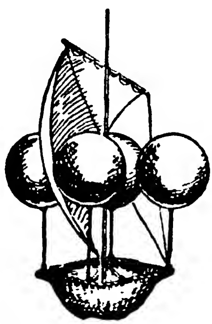

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THE BOOK OF INVENTION

CHAPTER I

PRIMITIVE INVENTIONS

Man's Debt to the Inventor—The Beginning of Invention—Necessity the Mother of Invention.

AS we read the story of invention it is wise to remember the 'once upon a time' when all things had their beginning. Only thus do we realize that we are kin with our earliest ancestors and understand that it is mainly in the advantages we enjoy that we differ from the cave man.

We live to-day in a world of marvels, but few of the wonders which we usually think of as the products of our own time do not have their roots in a distant past, and the first germ of an idea usually eludes our search because there is ever something that went before.

The chronometer, for instance, that marvel of delicate mechanism which keeps time with almost the accuracy of the sun itself, was born when a clever Greek added a cog-wheel to the water-clock, and that simple instrument owed its origin to the happy thought of one who had realized the need of all for an instrument more useful than the sun-dial, which speaks only when the sun is shining. The sun-dial itself carries us back a long, long way, and we can be assured that even that hoary clock was but a development of means used in the Stone Age to mark the passing hours in the dawn of mankind.

Then, again, a monkey cracks a nut with his teeth, but some early man discovered that he could save his teeth by using two stones. He was an inventor, and took the first step upward on the long ladder which has ended in giving us the marvellous modern flour-mills driven by steam power, with their steel rollers and silken sieves.

And so we hold the two ends of this thread that runs through the ages, and knowledge should make us thankful to the countless inventors who have contributed so greatly to brighten our lives and to make them vastly easier than those of our ancestors. Invention binds us to all who have gone before, even to the remotest bounds of time.

But our debt to the inventor is so great that it takes hard thinking to realize it. Every single thing around us—the clothes we wear, the chairs we sit upon, the glass in the windows, the lamp by which we read, this book itself—all these things had to be invented. But for the inventor we should be living in trees like the monkeys, without clothes, or shelter, or food except nuts and wild fruit. The story of invention is the story of civilization and of how man rose from savagery to his present state of civilization.

Of man's earliest inventions we know very little. The first may have been the use of a stone to crack a nut. The next was possibly the use of a stick to strike an enemy. Once man found that sticks and stones were useful, it was only a step, though perhaps a long one, to the making of a rude weapon by fastening a stone to the end of a stick.

Man used sticks and stones long before he dared to meddle with fire, for early man resembled the wild creatures in his dread of fire. Fire, of course, existed, for lightning must sometimes have set the forests ablaze just as it does to-day; while in those days volcanoes were much more frequent and active than they now are. The forgotten hero who first dared to tame fire to his

own use was the greatest of early inventors, for once man had fire he was master of all the lower creatures.

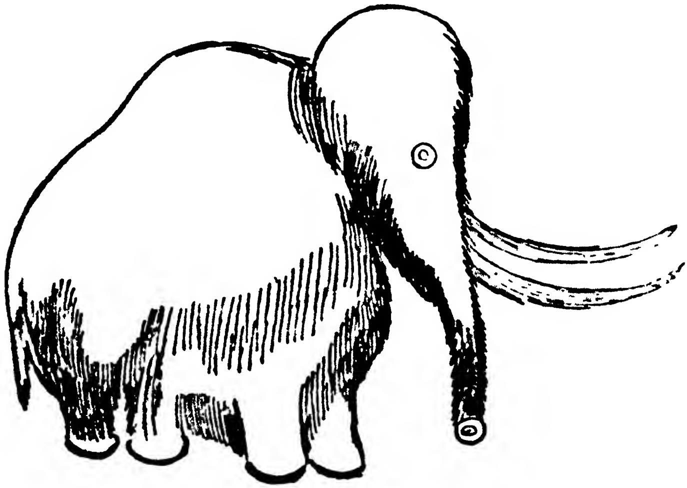
'Hero' I have written, but I should have said 'heroes,' for without doubt fire was tamed not by one man but by many different individuals at widely different times in different parts of the earth. Civilization, please remember, did not begin in any particular place or at any particular date. In those long-ago days there were many tribes small or large in numbers, entirely isolated from one another, and all slowly struggling upward. Some of these hardly rose at all, others with better brains rose to a comparatively high pitch, yet only to be wiped out by flood, earthquake, or some similar calamity. Each of these races developed along its own lines, and often very unevenly—so unevenly, indeed, as to fill our minds with astonishment when we realize it.

You ask how we know such things about peoples who vanished long, long before the dawn of history, and I answer that we learn by digging in the earth and discovering their burying-places, and by searching in the caves which were at that time their only homes. We can also tell a good deal by carefully observing those few races who are still entirely uncivilized, such as the natives of Central Australia, of Central Africa, and of the great forests of South America.

Some of our discoveries go to prove what I have already stated with regard to the comparatively high pitch of civilization to which very early races attained. At Combarelles in the French department of Dordogne a cave has been discovered the walls of which for a distance of three hundred feet are literally covered with prehistoric drawings, or perhaps one should say carvings, for the lines are cut deep in the rock. These drawings represent various animals, among them being the mammoth or woolly elephant, which has been extinct for a very long time. By this and other evidence we know

that these drawings were made at least twenty thousand and perhaps twenty-five thousand years ago. Yet the work is beautiful, being far superior to that done by other races who lived thousands of years later.

Even more recently, in another French cave on a tributary of the Garonne, there have been found a large number of clay models of animals, some about five feet



FROM THE PAINTING OF A MAMMOTH ON A CAVE WALL

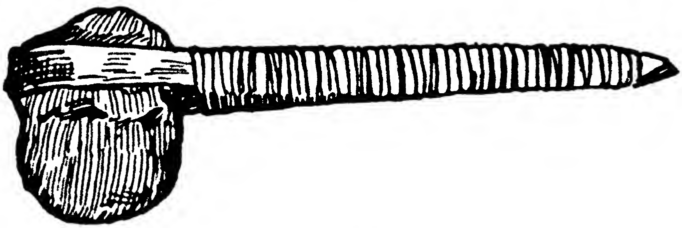
long, which have been preserved by stalagmite, a glassy substance formed by water dropping from the roof. These, too, are evidence of high art in a period enormously remote.

Still another proof of the curiously uneven growth of inventive genius is given by the natives of Australia. When white men first came in touch with the black-fellow about a century and a half ago they found a people who seemed lower than any yet discovered. These natives had no clothes, no pottery, they lived largely on insects and reptiles, they had absolutely no idea of tilling the ground or domesticating animals. They were, in fact,

on a level with the Palæolithic or 'Old Stone' people who inhabited England some seventy thousand years ago.

Yet these people used the boomerang, that strangely-shaped piece of wood which can be thrown so as to return through the air to its thrower. How they had invented such a weapon no one has been able to imagine, but the fact remains that they did invent it, and had been using it for centuries before the white man arrived to stare in wonder at such an amazing device.

All the early inventors were naturally influenced by their surroundings. Those who lived in a country where



A MODERN STONE AGE AXE FROM CENTRAL AUSTRALIA

flints were common were better off than those whose home was in a country where there were no hard, sharp-edged stones. So the flint-country people got on more quickly than their less fortunate neighbours.

Among the early inventions of these people were knives, spears, and scrapers, as well as clubs and hammers. The knives and spears enabled them to kill animals for food and cut them up when killed, and it was the people who got food most easily who found most leisure in which to perfect new inventions.

Tribes living near the sea used shells. Shells are very hard, and, when broken, have sharp edges, so we must take it that these seashore peoples also got started quite early in the making of tools. Quite lately the natives of the Andaman Islands were still using keen-edged shells for sharpening arrows made of cane and

bamboo, and as knives for cutting meat or thatch to roof their huts. They also had nautilus shells for drinking-cups and larger flat shells for plates.

When man had made himself weapons with which to kill animals he found the skins of these animals useful to keep his body warm. At first he merely wrapped the untanned hide round his naked body, but after a while it occurred to some inventor to cut holes through which to thrust his arms. After that, some one must have discovered that, by scraping and pounding a skin, it could be made soft. So clothes of a kind came into being.

A BOWMAN OF THE LATER STONE AGE

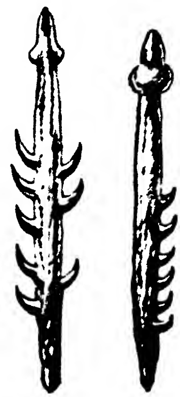
Another very early invention was the bow. The spear made of a flint-head fastened upon a straight piece of wood was a very ancient discovery, and was at first used merely in hand-to-hand fighting. Then some genius discovered that a spear could be thrown, and so made to kill at a distance. The next step was probably the invention of the throwing-stick for hurling a spear, and at last some one strung a strip of hide to the two ends of a springy cane and so was able to drive a light spear or arrow to a considerable distance.

A great advance was the discovery of the fish-hook. This we know to have been a very early invention, for fish-hooks made of bone are found in some of the oldest graves. The discovery of the fish-hook would, of course, enable its owner to gain an immensely larger supply of food with very little extra trouble, and, as I have already

pointed out, it is only when savages have a sufficient food-supply that they are able to spend time on inventions.

Whether the fish-hook led to the invention of the boat or the boat to the fish-hook we have no means of knowing. It does not require much power of thought to realize that a floating log will sustain a weight greater than itself, but the first man who hollowed out a log into the form of a canoe was a very great inventor indeed.

Another was the person who first made a dish out of clay. No pottery is found in the earliest burying-places, so we know that this is a more modern invention than the spear, the bow and arrow, and the fish-hook.



BONE HARPOONS

We have no knowledge whatever as to who first made a vessel of clay, or where it was made, but necessity being the mother of invention it seems likely that some early cook was the inventor. After fire had been mastered it was at first used only for protection against wild beasts. Later it came into use for cooking, but only for the roasting of chunks of meat. The art of boiling came later still, and the earliest saucepan was merely a tightly woven basket filled with water, into which red-hot stones were dropped until the water boiled. Then came pots of soapstone, but these were hard to make and had to be very thick or they would crack when put upon a fire.

Clay is found almost anywhere, and it is so soft and easily handled that every child loves to play with it. No doubt some savage genius, having amused himself by moulding a piece of clay, happened to notice that the article, whatever it was, having stood out in the sun for a day or two, became almost as hard as stone. Then what more natural than to copy the soapstone pot in clay?

All the earliest pottery was merely sun-dried. It was

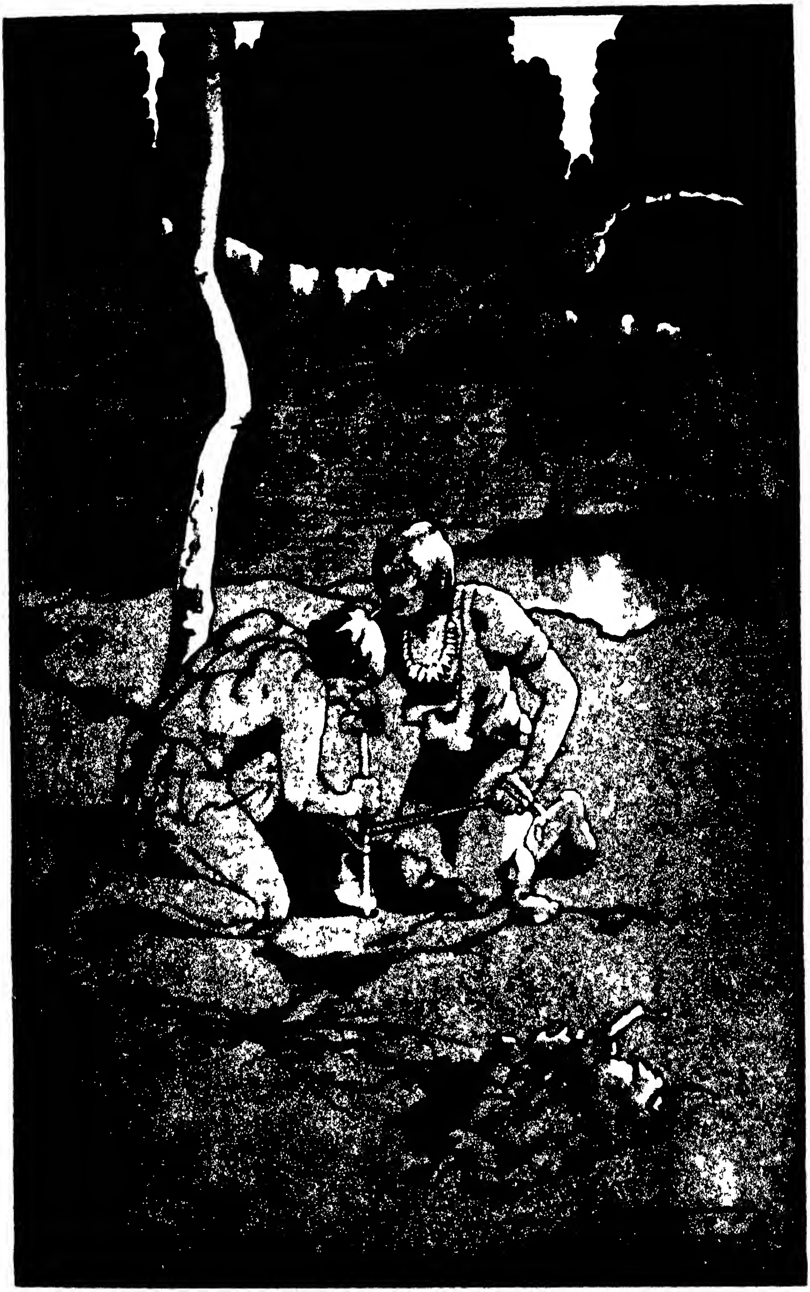
perhaps a long time before the discovery was made that clay articles burned in a fire were harder and more waterproof than those dried in the sun. It is an interesting point that the Australian savages, who were clever enough to invent the boomerang, never dreamed of making pottery. They still cook in open fires and pits and drink out of shells or gourds.

PERUVIAN TERRA-COTTA VASE

The finest of early clay-workers were those who lived in Mexico and in the Southern part of the United States. Very long ago they learned how to temper their clay with powdered shells and other materials, and much of their pottery was very beautiful in shape and most daintily ornamented. In Africa, too, many of the tribes have been expert potters from time out of mind. They use clay taken from the hills of the white ants, which has already been mixed and kneaded by these little mound-builders.

The Eskimo tribes of the Arctic, when first discovered, heated their snow huts and cooked their food by means of lamps. These lamps were shallow dishes cut from soapstone and filled with blubber. The wick was made of twisted moss. There is a part of Arctic America where soapstone is not found, and here the natives were found to be using stoves made of clay. The clay was kneaded up with seal-blood and hair, and in this way rendered tough enough to be used without much drying, for the sun in the Far North does not give sufficient heat for thoroughly drying clay.

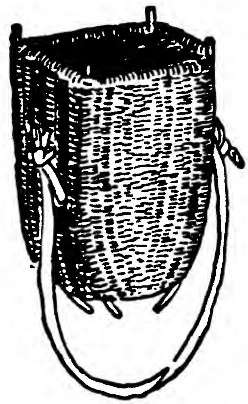
Even before pottery was first made it is probable that the art of weaving was discovered. The first articles woven were baskets of reeds or grass or wicker. As the



MAKING FIRE WITH STRAP-DRILL

weavers became more adept they used vegetable fibres for making cloth, and from that it was only a step to using the hair and fur of animals.

Some of the peoples of the Pacific Islands never needed to weave, for they had trees the inner bark of which provides a dress material almost ready made. The natives of Hawaii used the bark of the paper mulberry, out of which they made a material called *tapa*. The bark was taken off in strips six feet long and two inches wide, and these strips were dried in the sun. When required for use the strips were soaked in water and beaten with a round club on a smooth stone until formed into a kind of felt. The stuff was then dyed. And speaking of clever savage inventions, the Hawaiians were making for themselves waterproof garments long before such things were ever dreamed of in Europe. This they did by soaking their *tapa* cloth in coconut oil.



A CARRYING BASKET MADE BY NAVAHO INDIANS

In spite, however, of the ease with which bark cloth is made, some of the Polynesian natives do most exquisite hand-weaving. They use filaments of bark split from the hibiscus shrub and weave wonderful robes and sleeping-mats. Civilized man has never been able to compete with so-called savages in the perfection of hand-weaving. One example with which we are all familiar is the Panama hat, the best of which are so closely woven that they will hold water like a pail.

In order to procure yarn for weaving it was necessary to find means of twisting fibrous substances into rounded strands.

The spindle for spinning is a very old device, and, in its simplest form, was nothing but a rod of wood on which the yarn was wound.

String or binding material of some sort was one of the earliest needs of man, and was obtained from many different sources. In hot countries 'coir,' a fibre prepared from the outer husk of the coconut, has been used for thousands of years past, but in colder climates the sinews from the legs of the larger animals answered the purpose. These were cleaned and dried; then, when picked over, were ready for use. Twisted together, the short lengths were made into bowstrings, and even to-day Eskimo women use them for sewing together the furs of which they make clothes. The Eskimo woman has no scissors for cutting out, but uses a stone or metal knife; her needle is made of bird-bone, and, with her thread of sinew, she draws the edges of the skins so firmly together that the garment, when finished, is absolutely watertight.

The Eskimo make the most wonderful twine out of raw hide, and they perfectly understand the art of netting.

Foot-coverings came later than clothes, yet must have been used for a very long time. Tribes who lived in places where thorns were plentiful made themselves sandals of raw hide to protect their feet; others whose homes were in hot desert countries made sandals to save their feet from the burning sand. Others, again, who lived in the Far North, were obliged to invent foot-gear to save their toes from being frostbitten.

Speaking of boots and shoes brings us to means of travel.

Roads are quite a modern invention, and for ages and ages the pack-animal was the only means of conveying weighty goods from one place to another. Yet the sledge must have been invented tens of thousands of years ago, and if we go back to the very dawn of written history we find that wheeled vehicles were in common use. The origin of the wheel is lost in the mists of the Past, but even savages understand its principle. It grew, no doubt, from the roller. Mr Henry Elliott tells how a tribe of Eskimo, who had never before come into touch with

civilization, used rollers made of inflated seal-skins so as to pull a big canoe up over a shingly beach without damaging her delicate skin. In some way such as this it may well be that the idea of the wheel first came into being.

Man has always been a fighting animal and war taught the early peoples a great deal. It made them invent weapons. From bare fists and stone clubs they went on to spears and sabres with stone blades, and battle-axes. Then, in order to kill at a distance, they invented the boomerang, throwing-spears, bows and arrows, and slings. The sling is, perhaps, as ancient a weapon as the bow and arrow. Some tribes were clever enough to invent new weapons, such as the blow-gun of the Indians of Guiana, shooting poisoned darts, which is the ancestor of our air-gun. Another peculiar weapon is the *bolas* of the Patagonian Indians. This consists of two stone balls fastened to thongs of raw hide, which are thrown to considerable distances, and made to twist round the legs of a wild animal or enemy.

Early man also learned to protect his body with shields and armour. When the Red Indian tribes were first discovered they were using body-armour made of rods of wood laid parallel and woven together. The Mexican Indians wore padded cotton to save their bodies from arrows and spear-heads. War also taught bodies of savages to work together, to be obedient to discipline, to fortify their villages, and to signal at a distance. It sharpened their wits in a hundred different ways.

All our modern inventions are merely the savage devices worked out. The match descends from the friction-stick with which the savage made fire, the flour-mill from the ancient quern, the gun from the blow-pipe, while the Eskimo *kayak* or hunting-canoe was the forerunner of the magnificent modern yacht. All these are monuments to forgotten inventors.

CHAPTER II

DISCOVERIES OF THE ANCIENTS

The Bronze Age—Why Bronze came before Iron and Steel—The Ancient Egyptians as Inventors—The Discovery of Glass—The Romans as Inventors—Lost Inventions—The Dark Ages.

GEOLOGISTS class the ages of man as (1) the Palæolithic, (2) the Neolithic, (3) the Bronze, (4) the Iron. 'Palæolithic' means 'Old Stone,' and refers to the time when man subsisted by hunting with weapons made from flaked flints and bone or horn. 'Neolithic' means 'New Stone,' the age in which man found out how to cultivate the earth and to tame animals. After that came the Bronze Age when men first smelted metals and made tools with cutting edges.

Now please do not imagine that these various ages are divisions of time, for they are nothing of the sort. As I have already pointed out, some races got on with the business of inventing a great deal more rapidly than others. So all these four so-called ages may and actually have been in progress at one and the same time in different parts of the earth. For instance, the Red Indians were a Neolithic people when first discovered by Europeans, but the blackfellows of Australia, who were not found until much later, were still in the Palæolithic state.

No one can so much as guess when or where man first smelted metal, but in any case it was a very long time ago. Very possibly the art was accidentally discovered. A hot fire built on a rock containing tin might have melted out some of the metal, and one of the tribal inventors would no doubt have noticed how the shining stuff hardened as it cooled.

Tin by itself is soft stuff no good for making knives or spears, and copper by itself is not much use for any similar purpose, but when the two are melted together, forming what is termed an alloy, then this alloy, named bronze, is very much harder than either of the individual metals.

You will no doubt ask why bronze was invented before iron. The answer is simple. Both tin and copper melt at a much lower temperature than iron. Tin, indeed, will liquefy in an ordinary hot fire, but iron requires a far greater heat to melt it. It was not until men had become clever enough to use a bellows to increase the heat of a fire that they were able to use iron. So, although iron is a much commoner metal than either copper or tin, it was not discovered until a very long time after bronze came into use.

It is useless to try to guess how men first discovered that tin and copper mixed together made bronze, but we do know that bronze was in use at least five thousand years ago, and we have good reason to believe that the ancient folk who used it had secrets of their own for tempering or hardening it in a way which has been lost and never rediscovered. The modern man who made himself a razor of bronze would have a very poor time if he tried to shave with it, but the ancients made sickles, knives, swords, spears, saws, and razors out of this metal. Bronze was the metal used by the old Egyptians in all their wonderful works, and the Greeks, Etruscans, and early Romans were almost entirely dependent on bronze. We find quantities of bronze implements in ancient tombs and have discovered that the usual alloy was nine parts of copper to one of tin.

The invention of bronze was not made until man had given up his wild, wandering existence as a hunter and had settled down to till the ground, and to keep the wild animals—cattle, sheep, and horses—which he had tamed. It was a tremendous step forward, for until he had metal

tools man could not begin to build houses and cities, or to make all those thousand-and-one articles which depend upon metal for their manufacture.

While bronze was probably the first alloy to be made by man, the people of old knew of several other metals. In the Book of Numbers (chapter xxxi, verse 22), Moses speaks of gold, silver, brass (or bronze), iron, lead, and also 'bedil,' which is probably tin. But iron when first separated from its ore is comparatively soft, and it was no doubt a long time before some early inventor managed to alloy it with charcoal so as to form that much harder substance, steel.

The Egyptians were the great inventors of antiquity, and the beauty of the articles found in their tombs fills us to-day with surprise and admiration. A wonderful collection of these things may be seen in the British Museum.

The Egyptians were probably the first makers of glass. There are in the British Museum Egyptian glass vessels dating back to the year 2300 B.C., so that these are now forty-two centuries old. The story of the invention of glass, according to Pliny, a famous Roman writer, is that certain Phœnician merchants who had landed on a beach to cook their food happened to rest their pots on blocks of 'natron' or soda taken from their vessels' cargo, and found glass produced by the union under heat of the alkali and the sand. The historian Josephus attributes its discovery to the Jews, but others besides Pliny ascribe it to those wonderful traders the Phœnicians. At any rate, the art of glass-making spread throughout the ancient world, for we know that the Assyrians made glass, and that the Persians drank out of glass vessels. The people of India not only made glass but discovered how to colour it and to produce imitations of precious stones. In the year A.D. 200 there were so many glass-blowers in Rome that they had their own quarter of the city.

To return to the Egyptians, these people had also wonderful skill in tool-making. Some years ago the explorer Professor Flinders Petrie, digging in some ruins in Egypt, discovered a chest of tools of an Egyptian mason, probably thirty-two hundred years old. Among them he found a drill that was spiral so that in drilling into granite a core was left. The drill was so made that when the workman had cut the hole as deep as required he could sever the core and lift it out. Professor Petrie not only found the drill, but three of the cores, and he asks: " Is there any drill made in Europe to-day that could do work like this? "

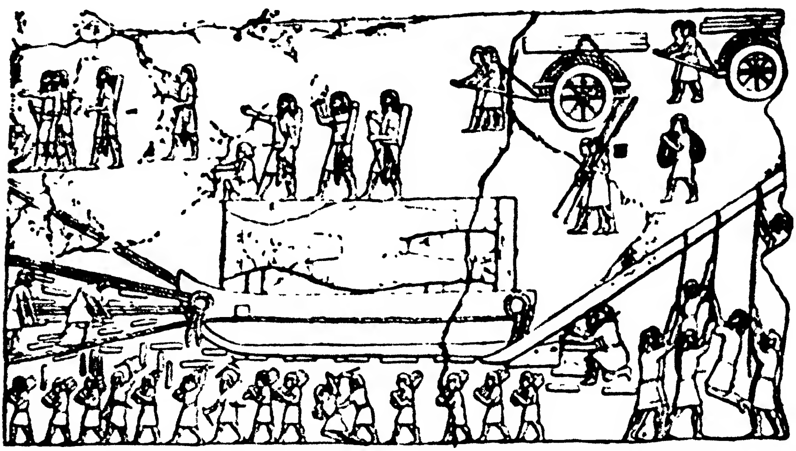
We have good evidence that for cutting hard stone the Egyptians used saws and hollow drills set with jewels, and these were worked under great pressure. We are, however, quite ignorant of how the jewels were fixed in the metal supports so as to stand the heavy strain upon them. Even with modern appliances it has always been difficult to fix diamonds in a saw or drill so firmly that there is little chance of their working loose. The Egyptians made babies' feeding-bottles out of baked clay, and not long ago there was found a bone collar-stud just like those sold by hawkers in the streets, yet which was made long before Moses marched the Children of Israel out of Egypt.

The ancient Egyptians had doctors and surgeons. We have found probes, forceps, and other surgical instruments in their tombs. They were also good dentists. Jaw-bones of mummies have been found with false teeth in them, and with teeth stopped with soft gold. In connexion with false teeth, it is rather interesting that there is mention of these in early Roman laws. The first part of Number Ten of the " Laws of the Twelve Tables " forbids useless expense at funerals, but it is expressly stated that the gold fillings of the dead person's teeth may be buried with the deceased.

The Egyptians had a preparation for preserving statues

and stonework against the effects of weather, but the secret of this has passed with them. Again, they probably had magnifying-glasses. That the magnifying-glass is a very ancient invention we are certain, for some time ago the explorer Layard found in the ruins of Nimroud a magnifying-lens of rock crystal which Sir David Brewster pronounced to be a true optical instrument.

The Egyptians must have possessed a pretty good



TRANSPORTING A HUGE BLOCK OF STONE AT NINEVEH, 660 B.C.

From a bas relief

Ancient artists were careless of perspective, and so the wooden rollers are shown side on instead of end on, as they would have been used.

knowledge of chemistry; they had the decimal system of numbers and an excellent system of weights and measures; while the way in which they and other ancient peoples transported enormous blocks of stone over great distances is certain proof that they knew much about engineering. They embalmed their dead kings so perfectly that the bodies are in splendid condition to-day. The secret of how they did this is lost, and so, too, is a great deal of the wonderful knowledge which they gathered during the thousands of years of their life in the rich valley of the Nile. Much of this knowledge was, no doubt, preserved in that

marvellous library at Alexandria which at one time is said to have contained 490,000 volumes. The destruction of this library, begun in the time of Theodosius by a mob of religious fanatics and completed by the Arabs under Omar in the year 641, is by some people considered to have been one of the worst disasters which ever befell civilization. Others are, however, of the opinion that the destruction of these records opened the door to new ideas, new thought, and new inventions.

The ancient method of embalming bodies is only one of many secrets of old time which have been completely lost to the world and have not been rediscovered.

The Romans understood the principle of the lightning-conductor. On the summit of the highest tower of the Castle of Duino on the Adriatic there was set from time immemorial a long rod of iron. A soldier was always stationed near it in stormy weather, and from time to time he put the metal point of his spear close to the iron. Whenever a spark passed between the rod and the spear he rang a bell to warn the fishermen.

The Chinese and Egyptians understood how to bore to great depths for water, and the Romans sank artesian wells; but exactly how they did the boring we do not know. Knowledge of these wells was lost for more than a thousand years. The oldest artesian well known in Europe was sunk in the year 1126 at Lillers in the French province of Artois, hence the name 'Artesian.'

The Greeks had a way of weaving linen or wool to form the *pilema*, a sort of cuirass which could not be penetrated by the sharpest of darts or arrows. This secret is lost—perhaps for ever. Malleable[1] glass was made in the time of the Roman Emperor Tiberius. Neri, whose book on glass was published at Florence in 1612, speaks of this invention and says of it: "A thing after-

[1] Malleable, that which can be pressed into a different form without breaking.

ward lost, and to this day wholly unknown, for if such a thing were now known, without a doubt it would be more esteemed for its beauty and incorruptibility than silver or gold, since from glass there ariseth neither smell nor taste or any other quality."

The art of making glass that would bend but not break was also practised in Persia. It is said that in the 17th century a French inventor rediscovered the art and presented to Cardinal Richelieu a bust made of malleable glass. He was rewarded for his ingenuity by imprisonment for life, lest the interests of the French glass-workers should be injured by the new invention.

This incident recalls to mind the unhappy history of the man who first discovered that very light metal, aluminium, of which we make such great use to-day. The Roman historian Pliny, who lived between A.D. 23 and 79, relates how a certain worker in metals appeared at the palace, bringing to the Emperor Tiberius a cup composed of a brilliant white metal which shone like silver. While the artificer was presenting it he purposely dropped it on the marble floor of the chamber and bruised it so that it seemed injured beyond repair. But the workman took his hammer, and in the presence of the Court repaired the damage. The Emperor took the cup and noticed that it was far lighter than silver. He then questioned the man, who told him how he had extracted the metal from clay (no doubt that known to the modern scientist as *alumina*). Tiberius then asked if anyone except the maker knew the secret, and the other proudly replied that it was known only to himself and Jupiter.

The Emperor turned to his guards and ordered them to take the inventor out and behead him instantly, and afterward to destroy the man's workshops. The reason he gave for this brutal order was that if it were possible to obtain so wonderful a metal from clay the value of

his own hoards of gold and silver would be reduced to nothing.

Yet in spite of this dreadful example the Romans invented many things. They had, for instance, a water-supply brought from a great distance by nine wonderfully constructed aqueducts, three of which still supply the modern city; they had a system of drainage which was far ahead of anything that London possessed a

ROMAN AQUEDUCT NEAR N

hundred years ago. They had water-mills for grinding wheat and other grain and for pressing olives. They even had saw-mills. Water-clocks for measuring time were introduced in the year 157 B.C. by Scipio Nasica.

We are aware that Rome under the Emperors had become a city of sky-scrapers, or at any rate of houses many storeys in height. Centuries elapsed before any other nation dreamed of constructing similarly lofty edifices. Roman architects even understood the principle of the lift, for excavations in Rome on the site of the Cæsars' palace on the Palatine have proved that at

least three large lifts were used to enable the Emperors to ascend from the Forum to the top of the Palatine.

So excellent was the Roman masonry that in many parts of Europe—in Portugal, for instance—walls of Roman bricks that were built more than fifteen centuries ago are still standing. Not only were the bricks excellently made and burned, but the cement and mortar, which are the weakest parts in a modern wall, were made according to recipes long since lost. In Roman and Greek buildings the mortar remains good even after the stones or bricks have crumbled with age.

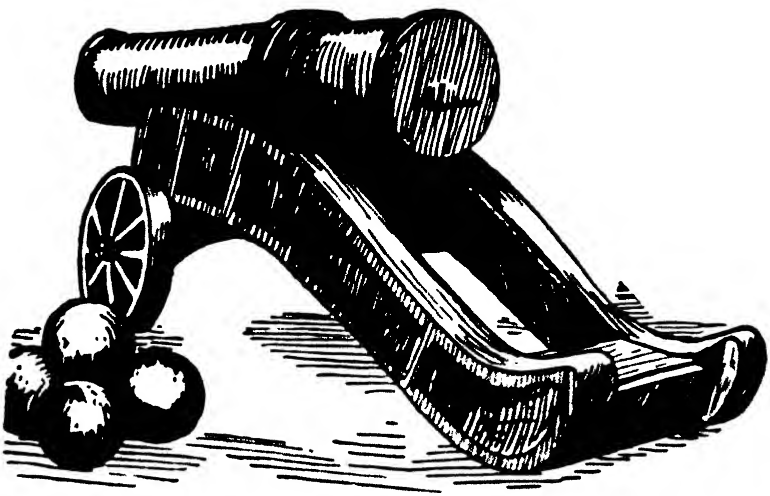
Greeks and Romans both understood the manufacture of most beautiful and brilliant dyes, and they were able to make ink which was durable and lasting.

Other secrets of the ancients which we have lost are those of Damascus steel and Greek fire. Even modern Sheffield cannot produce sword-blades such as were used by the Saracens centuries ago. The steel of which they were composed was so keen, hard, and tough that it could shear through chain armour. Of the exact nature of Greek fire we are ignorant. It was, however, a liquid composition which could not be extinguished by water or other ordinary means. The secret probably came to the Greeks from the East, and the fire was used with terrible results by the Byzantine Emperors.

The Western Roman Empire went to pieces in the year 476 and the whole Western world fell back into a state little better than barbarism. For centuries every one was fighting. Men were either soldiers, merchants, monks, or slaves; very few people could read, fewer still could write, and all the arts were neglected. The monks were the only people who had any education. Even theirs was not a very high standard, and their superiors did not encourage them in invention or discovery; nevertheless practically all the work that was done for invention during the ten terrible centuries of that period stands to their credit.

Discoveries of the Ancients

During the Middle Ages Western man hardly climbed a single rung up the ladder of civilization. The inventions of the ancients were neglected or forgotten, and almost the only discoveries that were made were concerned with the art of war. The most important, that of gunpowder, is usually ascribed to Roger Bacon in the 13th century. But since some sort of explosive mixture of the kind was known long before his day and was actually used against



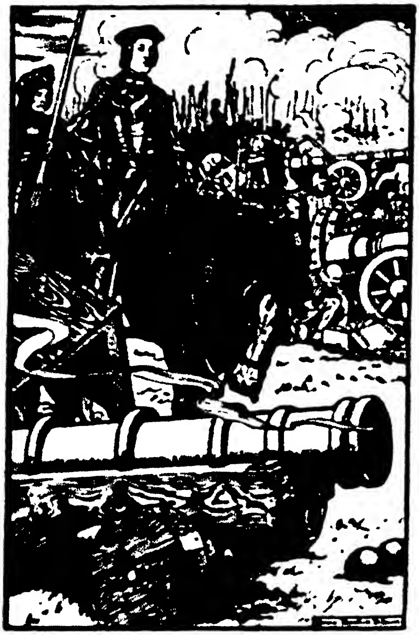
MONS MEG

the Crusaders in the form of rockets, it is probable that Bacon was merely the first person to make gunpowder in England. In any case, his mixture was so poor that it was of little practical use, and it was not until the year 1320 that the German monk Berthold Schwarz discovered a way of mixing the various ingredients so as to form a powerful explosive.

Seven years later, Edward III used rude cannon called 'crackeys of war' against the Scots, and in 1346 he used similar weapons at the battle of Crécy. Yet for more than two centuries after that date all the powder used in England was imported from the Continent; it was not

until the time of Queen Elizabeth that powder factories were established in Surrey at Long Ditton and Godstone.

Cannon, it will be seen, followed close upon gunpowder. The first were made of iron bars hooped together with iron rings; they were wider at the mouth than in the chamber; they fired stone balls, and were almost as dangerous to the users as to the enemy. James II of Scotland, for whom was built the great gun 'Mons Meg,' now preserved at Edinburgh Castle, was killed by the bursting of a similar piece called 'the Lion.' About the year 1401 cannon were cast in one piece of bronze, but it was not until another sixty years had passed that we first hear of cast-iron guns. Edward IV seems to have been the first English king to make serious use of cannon, and in 1470 his artillery put the rebels under Sir Robert Welles to such hasty flight that they left their coats upon the field of battle. The greatest gun of the 17th century was made in India, at Bijapur, of cast-iron. It was fourteen feet long, twenty-eight inches bore, and hurled a giant ball weighing sixteen hundred pounds. In these days all big guns had names, and this monster was known as 'Malick è Meidan,' or 'Lord of the Plain.'



EDWARD IV WITH HIS CANNON

Of peaceful inventions of the early Middle Ages the most useful was that of spectacles. The earliest reference to spectacles is by an Arab writer of the 11th century,

and the famous Roger Bacon also speaks of them. Their invention is usually attributed to two Italian monks who lived during the 13th century. Early spectacles were very heavy and clumsy, and they were not much improved for nearly five hundred years.

I have spoken of water-clocks made by the Romans, and no doubt you have heard of the device of King Alfred, who cut notches upon candles in order to mark the time.

The first clock of which we have any distinct record was made for the town of Magdeburg in Germany, about the year 996, by a monk named Gerbert, who afterward became Pope Sylvester II. This machine was worked by a weight. A century or so later, clocks began to be fairly common in the larger monasteries, but they were not much like our modern clocks. They were simply arrangements which rang a bell or struck a gong at regular intervals to call the monks to meals or prayers. They had not faces marked with the hours, nor hands.

It was not until the 13th century that we hear of clocks in England. In 1286 St Paul's Cathedral had a clock-keeper. A little later, Westminster, Canterbury, and Exeter Cathedrals were the possessors of clocks. The oldest clock which is still in existence may be seen in the South Kensington Museum. It was made by Peter Lightfoot, a monk of Glastonbury Abbey. The great Abbey is now an ivy-clad ruin, but Peter's clock, made five hundred years ago, is still in excellent order. The first clocks were huge and massive; portable clocks were first made early in the 14th century.

The Chinese assert that the mariner's compass was invented by their Emperor Hoang Ti, in 2634 B.C. The Chinese claim that they were the originators of most of the great inventions is not fully accepted, but in this case there is no doubt that they understood the properties of a magnetized needle long before the Western peoples. By

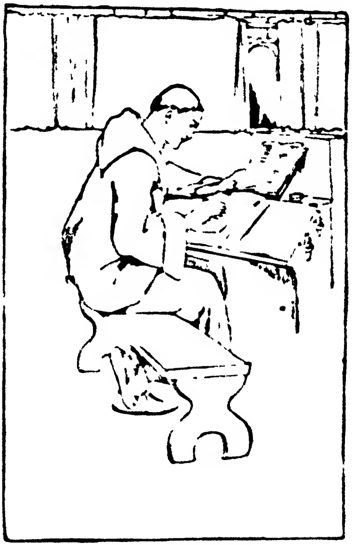
some it is supposed that the great Italian traveller Marco Polo brought the compass to Europe from China, but there is evidence that this instrument was rediscovered in Europe in the 12th century. The Norse adventurers were the first to make practical use of this device, which is certainly much the most important of the inventions during the Middle Ages.

CHAPTER III

THE GREAT AWAKENING

The Discovery of Printing—John Gutenberg—The Revival of Invention—William Lee and his Stocking Frame—Galileo's Telescope and Jansen's Microscope.

IF the ancients had understood the art of printing it is more than likely that mankind would never have been forced to pass through that long and dreadful time of war and misery which we call the Middle Ages. The Egyptians and Greeks and Romans had many clever men, great artists, teachers, and inventors, much of whose knowledge was actually written down; but since, before the invention of printing, the only way to circulate a book was to copy it by the long and slow process of writing by hand, very few copies were made, and these only came into the possession of persons rich enough to be able to pay for the copying.



A MONK WRITING

Of many books written in those days there were only one or perhaps two copies, and, when the flood of barbarism swept down upon Italy and Gaul from North Europe, the greater number were destroyed and all the knowledge contained in them was lost. The wise men and teachers were either killed or made into slaves; education, which in those days was mostly by word of

mouth, ceased, and within a few generations the whole Western world dropped back into barbarism, from which it hardly began to recover until the invention of printing.

At school I was taught that printing was invented by Gutenberg at Strasburg about the year 1440, but this statement is open to much doubt. The Dutch claim that Lourens Janszoon, surnamed Coster, who lived at Haarlem, cut letters on the bark of a beech tree, and printed from them, for the amusement of children; that afterward he invented leaden letters and printing ink, and printed on sheets of paper. Then, so it is said, one of his workmen stole some of his types, and ran away to Mainz, where he opened a workshop. The facts seem to be that before Gutenberg's time some rough attempts had been made at printing, but that Gutenberg and his associates were the first to set up a real printing-press and to make books in the modern sense of the word.

John Gutenberg was a man of good family, born at Mainz about the year 1400; but having been driven out of his home, he went to live at Strasburg with Anna, his wife. He had been well educated, and took up the trade of lapidary; that is, he cut and polished precious stones. His little shop was the front room of his house, and he made a fair living.

One evening, so the story goes, he picked up a playing-card and gazed at it. It must be remembered that even in those days the art of engraving was known, and the card had been made from an engraved wooden block. But it was very rough and coarse—needlessly so, it seemed to him. At any rate, he thought that he could improve upon the work, and he made the experiment. A few days later he showed his wife some cards, which delighted her, for the lines were much clearer and the colours brighter than in the old ones.

His success encouraged him, and he next cut his wife's name on a block of wood and printed it off on paper.

A picture of St Christopher hung on the wall, and he decided to copy and duplicate this. He had to make his own tools, to find the best wood from which to print, and to devise new printing ink. He did all this and so successfully that his copies of the St Christopher were better than the original—so much better that he had no difficulty in selling a number of them. He gave one to the Abbot at the Cathedral, who in return gave him a copy of the History of St John.

Then came to Gutenberg the great idea of making blocks of each page and so printing many copies of this book. With the aid of three apprentices he undertook this tremendous task, and completed it. He sold a few copies, but not many. In those days not many could read, and there was no great demand for books. He went to his friend the Abbot and told him what he had done, and the Abbot suggested that he should print copies of the Bible.

But when Gutenberg examined a copy which the Abbot had given him he found that there were no fewer than seven hundred pages, and that it would take him nearly thirty years to make blocks of them all. At first he was in despair, but, after thinking the matter over, he at last hit upon the idea of cutting out separate letters on small blocks of wood, and in a little time he had a real ' fount ' of type.

It was a wonderful advance; but even now his troubles were not ended, for it was difficult to hold the letters in position in the lines of type. He tried thread, he tried wire, but neither would work. Then at last the idea came to him of a kind of frame made something after the principle of a wine-press. And so the type was properly set, and the first printed Bible was issued.

But again very few were sold; the apprentices were disappointed, and one broke his oath and told others of the secret process. And so Gutenberg took the bold

step of breaking up all his type, for he vowed that he would not be robbed of the fruits of his invention. He and his wife then went back to Mainz, where his brother Friele was *still living*.

The brother, a good fellow, introduced John to a rich goldsmith named Faust, who promised to provide money for a new printing works. Work started again, but now

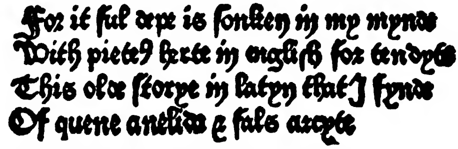
A PRINTER'S SHOP OF THE 15TH CENTURY

Gutenberg found that the ink softened the wooden letters so that they lost their shape. Again he set his brains to work, and once more perseverance conquered difficulties. He cut type out of metal, and began to print the Bible. But the sales were still small; and Faust, having spent four thousand florins, became impatient and suddenly demanded that John Gutenberg should pay up. Since the poor fellow had not the money, Faust seized the types and presses and turned John out to starve.

Friele, however, again came to his brother's help, and later the Elector Adolphus of Nassau gave John a comfortable

home in his old age, so that at any rate he did not die of starvation, as was the fate of so many of the early inventors.

Faust and a man named Schoeffer continued the printing, and brought out several editions of the Bible. Presses were set up in Hamburg, Cologne, and elsewhere, also in Florence and Venice. In Italy alone nearly thirteen hundred books were printed between 1480 and 1490, and so rapidly did the new invention now spread that by the year 1500 there were more than one hundred and thirty printing presses at work in Europe.



A SPECIMEN OF CAXTON'S PRINTING (REDUCED)

The man who brought the art to England was William Caxton. He learned it while travelling in Germany, and when he reached home set up a press at Westminster in the year 1476. Some history books tell you that the press was set up in Westminster Abbey, but this is absurd. The press was in the 'precincts' of the Abbey, a very different thing. Presses were soon set up at Oxford, Cambridge, and elsewhere, and printing flourished mightily until the year 1530.

CAXTON'S HOUSE AT WESTMINSTER

Then, when many men had learned to read, the Government suddenly got frightened, and started a censorship for the purpose of deciding what should or should not be printed. Needless to say, very little that was not agreeable to the authorities was allowed to pass into print.

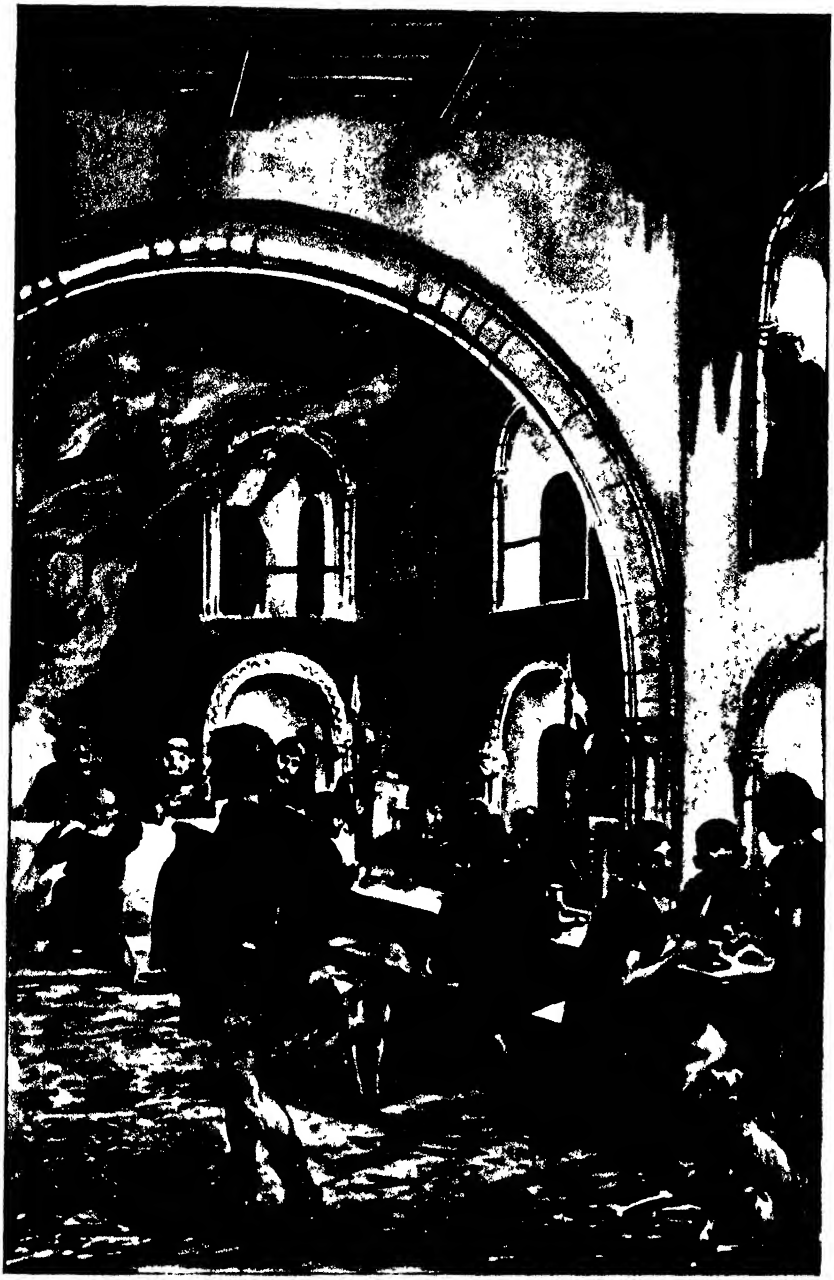
Printers who disobeyed the censorship were tortured by the abominable Star Chamber, and this persecution went on in England for more than one hundred and fifty years. It was the last gasp of the black horror of the Middle Ages. In 1694 the censorship was abolished, and soon the English people became the best printers in the world. To-day nearly three-quarters of all the newspapers in existence are printed in English.

Invention, which had been dead for centuries, began to revive at or a little before the date of the invention of printing. At the time of the Norman Conquest and for a long time afterward, even the king and his nobles lived in a state of squalor and discomfort which the poorest person of modern times would resent. There was no glass in the windows of their houses, there were no carpets or rugs on the floors. The clay or stone floors were strewn with rushes or straw and were filthy beyond words. Even the greatest castles swarmed with vermin such as we do not mention in polite society.

The only plates or dishes were of pewter, and only rich people could afford such. There were no forks or spoons. The smoking joint was passed round on a spit, and each person hacked off what he required with his knife and laid it on a cake of bread in front of him. The diners drank their sour beer out of a horn or pewter cup.

The beds were dreadful, being merely sacks stuffed with straw. The richer classes used coarse blankets, but sheets or night garments of any sort were unknown. There were no conveniences for washing. Indeed, few people bothered much about washing, for soap, I need hardly say, was as unknown as tooth-powder.

Old or delicate people suffered severely with cold in winter, for the only fire was in the great hall of the castle; and since the only chimney was a hole in the roof, stinging, choking wood-smoke filled the place. Nor were the clothes of those days calculated to keep their wearers



A CASTLE HALL IN THE NORMAN PERIOD
S. J. Robbins

warm. Undergarments, even for the few who could afford them, were made of coarse, hard wool, and socks and stockings were still inventions of the far future. Food was scarce and very bad. The bread eaten even by the rich folk was almost black, and there were practically no vegetables. Having very little feed to keep beasts under cover during the winter, it was the custom to kill nearly all the sheep and oxen in the autumn and salt their flesh. A diet of salt meat and bread without green stuff produced scurvy, which, since there were no doctors, killed more people during the Middle Ages than even the Black Plague or typhus.

Outside the house the state of things was equally hopeless. There were no roads, no carriages. Coaches were sternly forbidden, the idea being that if the nobility gave up riding on horseback they would become indolent and unfit for fighting. In the towns the streets were little better than open sewers. It was not until the year 1417 that any of the streets even in London were paved, while so late as 1605 many streets were still nothing but mire in which the wretched foot-passenger might sink to his knees.

As wealth increased—above all, as the endless fighting ceased, and people began to have some sense of security—they soon tired of these horrible conditions, and set to mend them by importing from other countries articles of use and luxury. Carpets were brought from the East; glass from Italy and France. In England there were no glass factories until about 1550. Soap, which was well known to the Romans, was reintroduced. About the end of the 15th century, forks, which had come into use in Italy, were introduced into England. These, and many other importations, set English brains to work in copying them, and so gradually the standard of living was raised, and there came about a great revival.

Even so, such things as were made were almost all made by hand. The only machinery in England before

the 16th century was driven by water or wind. The Romans established mills for grinding corn in England some eighteen hundred years ago, and a pair of old Roman millstones were found at Adel in Yorkshire. The first windmill of which we have any record was built in Venice in the year 1332 by Bartolomeo Verde. In places where there was no water-power, grinding mills were sometimes driven by cattle or by man-power.

For clothing, silks and velvets were purchased abroad, and such garments as stockings were invented. But even Queen Elizabeth herself, when she first came to the throne, wore stockings made of pieces of silk sewn together, for there were still no such things as woven stockings. I may mention that the 'clocks' which still ornament stockings were originally put on for the purpose of hiding the ugly seams up the sides.

Speaking of stockings brings us to the story of a very plucky and clever Englishman, the Rev. William Lee, the inventor of the stocking-frame. Lee, who lived in the days of Queen Elizabeth, was in love with a girl who, when he went to call upon her, was always busy knitting woollen stockings—so busy that she would not speak to him, and would pay no attention to his pretty speeches. The young curate put up with this treatment for a long time, but at last got disgusted—'fed up,' we should call it—and made the odd vow that he would do by machinery what she could do only by hand.

Once he started to invent a stocking-frame he became so interested that he forgot everything else. He even gave up his living. The girl was now sorry she had treated him so badly, and did her best to persuade him to go back to his church. But he flatly refused, and, working almost day and night for three years, at last perfected the world's first stocking-frame.

In high delight he posted off from Nottingham to London to show his wonderful invention to the Queen,

and ask for a patent—that is, a monopoly—for his new frame. The Queen shook her head. "Had Mr Lee made a machine that would have made silk stockings I should have been justified in granting him a patent," she said; "but a monopoly of making woollen stockings for the whole of my subjects would interfere with the means of subsistence of many poor people who knit for a livelihood."

Poor Lee was very much dismayed, but he did not give up hope. He found a friend in Lord Hunsdon, who bound his son, who was a knight, as apprentice to Lee. So the first machine stocking-maker's apprentice was a titled person and even of the blood royal.

Lee then set himself to invent a machine to make silk stockings, and in 1595 completed a machine which had twenty needles instead of eight, as in his first frame. Again he went to the Queen, and again he was turned away. Still he kept up his heart. His apprentices thought it so high an honour to work for him that each wore a needle with a silver shaft slung round his neck with a silver chain. Then Lord Hunsdon died and a little later his son also. Lee, almost ruined, went to France, where the King, Henry IV, was interested in his new invention, and helped him to set up a factory. Before it was finished the King was murdered, and the unfortunate Lee gave up hope and died at Rouen in 1610.

The way of the inventor has never been easy, but in those earlier days it was desperately difficult. People, even of the upper classes, were so ignorant and so prejudiced that the inventor, far from making a fortune, was usually lucky if he escaped with his life. A notable example is that of Galileo, the inventor of the telescope.

Astronomy, or the study of the stars, is a very old science. Aristarchus, the great Greek astronomer, knew that the earth was round and revolved round the sun. This knowledge was so completely forgotten that when Copernicus revived it seventeen centuries later he was

abused by every one and denounced by Luther as an 'arrogant fool.'

Galileo was born in the Italian city of Pisa in the year 1564, and from the first showed that he was far ahead of his age. It was at that time believed that a body weighing one hundred pounds would fall one hundred times as fast as one weighing only one pound. Galileo declared that this was nonsense, and proved it by dropping a half-pound weight and a hundred-pound cannonball from the top of the famous leaning tower. Both, of course, reached the pavement at the same time.

But if you suppose that this brought him fame or popularity you are much mistaken. The people vowed that he was a magician, and even the students hissed him. He shook off the dust of Pisa and went to Padua, where he invented his famous telescope. The first telescope was a rude instrument formed by placing lenses in a leaden tube, but very soon he had a telescope which magnified nearly a thousand times and brought distant objects thirty times nearer. The first things he discovered were the mountains on the moon, and soon afterward he saw the moons of Jupiter. Then he discovered sunspots. Filled with wonder and delight he began to tell the world of these marvels. At once the Inquisition stepped in. The sale of his book was forbidden, and a Commission was appointed to bring charges against him. The Commission reported that the astronomer had disobeyed the teachings of the Church by maintaining that the earth moves and the sun is stationary; and that he had wrongly declared that the movements of the tides were due to the movement of the earth round the sun. Also, that he had failed to give up these beliefs, although commanded to do so. When he still refused to be silent, Galileo, then nearly seventy years old, was dragged off to Rome and threatened with torture if he did not recant. Can anyone blame him

that he did so? In himself he knew that the truth could not be stifled, and he was right, for the new knowledge spread all over Europe and did much to disperse the black ignorance and superstitions of the past centuries.[1]

If the telescope enables us to study infinitely distant objects, the microscope is almost more important in that it permits us to see and study things so tiny that the strongest eye unaided can make nothing of them. Without the microscope, invention must have long ago come to a standstill and medicine would be still in its infancy. Doctors would know nothing of the germs that are now recognized as the causes of infectious diseases, scientists would remain ignorant of ferments such as yeast, metallurgists would have no means of studying the structure of metals, while natural historians would be without the instrument most valuable in their researches. I mention the microscope here because the first was made by a Dutchman named Cornelius Jansen during Galileo's lifetime, about the year 1590.

The first microscope was a poor thing, for it distorted objects placed under it. The world had to wait nearly a hundred and fifty years before the invention of the achromatic lens by Chestermoor Hall saw the beginning of a new era for the uses of the microscope.

It was the microscope which enabled Malpighi to discover, in the year 1661, the hair-like veins of the human body known as the capillaries. The great William Harvey had already, in 1628, discovered how the blood circulates through the body.

The 17th century saw a great revival in invention, and one of the greatest inventors of that period was an Englishman, the Marquis of Worcester, who wrote *The Century of Inventions*, and who himself was responsible for over one hundred different inventions, among others

[1] For other interesting references to Galileo see *The Book of the Heavens*, chaps. ii, ix, and x.

a steam apparatus which could raise a column of water to a height of forty feet. The Marquis was indeed the first inventor of the steam-engine, although he probably had no idea of the enormous value of his discovery to those who were to come after him.

If you will take the trouble to read the famous *Century of Inventions*, you will at once be struck with the fact that the Marquis was tremendously ahead of his time. For instance, he speaks of a way "to make a ship not possible to be sunk though shot at a hundred times between wind and water by cannon." The Marquis discovered the principle of watertight compartments, though it was not until two centuries later that his idea was put into practice. To-day not only warships but all large vessels are built with watertight compartments.

The same inventor had an idea for driving ships by paddles worked by a windmill on the deck. He invented a portable bridge, a canal lock, a pistol which would discharge a dozen times with one loading, or, in other words, a 17th-century revolver. He tried his hand at a flying-machine, and even had an idea for a world language, a sort of early Esperanto.

CHAPTER IV

IRON, TIN, AND STEEL

The Ironmasters—Smelting with Coal—Andrew Yarranton's Tin-plates and Abraham Darby's Cooking-pots—The Coalbrookdale Inventions—The Invention of Cast Steel.

ONE of the most wonderful men of 17th-century England was 'Dud' Dudley, a son of Edward, Lord Dudley. He was born in the year 1599. At that time Dudley in Worcestershire was already a centre of the iron manufacture, and there were said to be no fewer than twenty iron-workers living in and around Dudley Castle. Iron in those days was smelted, as it had always been, with wood, and nothing but wood, and Worcestershire, though formerly 'a mighty woodland county,' was rapidly being stripped of all its fine timber, with the result that charcoal for iron-smelting was fetching famine prices.

It had never occurred to anyone to attempt to use coal for smelting, and that in spite of the fact that there were seams of coal in the neighbourhood no less than ten feet thick, and ironstone four feet thick under the coal, and plenty of limestone (which is also needed for smelting) close at hand. Dud Dudley was the first of Englishmen, or indeed of inventors anywhere, to have the great idea of using coal instead of wood in the manufacture of iron.

Dud was at Balliol College, Oxford, when his father sent for him to take charge of an iron furnace and forges at Pensnet in Worcestershire, and the very first thing he found on arrival was that there was hardly any wood left in the neighbourhood. He resolved to use coal; but first he had to turn the coal into coke, which he managed by a

similar process to that used for turning wood into charcoal. Presently he was able to write to his father that he was making three tons of good iron weekly from each furnace, and in 1620 a patent was issued to him for the process which he had invented. He started new furnaces at Cradley, and sent some of his 'pit cole' iron to London, where it was tested and found good. A fowling-gun was made of this metal, which was 'well approved.'

Just a year later came a fearful flood, still remembered as the 'Great May Day Flood,' and swept the new works away. Instead of offering any sympathy, the iron-smelters of the district were overjoyed at the destruction, for they had seen Dudley turning out good iron at a price lower than that at which they could produce it.

Dud set his teeth and rebuilt his forges, and, in spite of violent opposition, proved that his iron was good for making muskets, carbines, anchors, and bolts for shipbuilding. He went on making great stores of iron, and selling it for twelve pounds a ton.

The ironmasters banded against him, brought lawsuits, and succeeded in getting him ousted from his works at Cradley. He moved to Hasco Bridge, near Sedgley, and built a larger furnace than any yet; here soon he was turning out seven tons of iron a week. He opened up new seams of coal, and was doing wonderfully, when a mob of rioters, instigated by the charcoal men, broke into the new works, cut his bellows, destroyed his machinery, and left the whole place in ruins. He, too, was ruined, was seized by his creditors, and put into prison in London.

Charles I took pity on the inventor, released him, and granted him a new patent, but this had hardly been done before the Civil War broke out. Dud at once took service with the King, and there for a time was the end of his iron-works. As he said in a petition made later on to King Charles II, " I was in most of the batailes that year, and also supplyed his late Sacred Majestie's Magazines

with arms, shot, drakes, and cannon, and also became Major unto Sir Francis Worsley's regiment, which was much decaied."

Taken prisoner with a number of others of the King's officers, Dud Dudley was dragged through Worcester and flung into gaol. He and a friend, Major Elliotts, managed to break out and escape. They were so hotly

RIOTERS DESTROYING DUDLEY'S WORKS

pursued that they dared travel only by night and in the daytime hid themselves in trees. They reached London, but only to be captured a second time and sentenced to death.

They were to have been shot on Monday, August 21, 1648, but, on the previous Sunday, Dudley and eleven other Royalist officers overpowered their gaoler and again escaped. In making his escape, poor Dudley got shot in the leg; but his will was like his own iron, and, managing to get hold of some crutches, he limped all across England

to Bristol, where he was taken care of by old friends. But he had lost everything, and he had not a penny left. His only possession was his secret process for making iron with pit coal, and after a time he persuaded two business men to put up the money to make a fresh start. But somehow he and his partners quarrelled, and there again was the end of his hopes.

Meantime all sorts of people were trying hard to smelt iron with pit coal, but all making an utter failure of it. Some tried to get Dud to help them, but no ! He kept his secret, and waited for the Restoration, when he petitioned for his patent to be restored to him. Charles II, that ungrateful monarch, did nothing to help the man who had been so good a friend of his father, and Dud, now growing old, at last seems to have given up hope. Yet he lived to be eighty-five years of age ere he found rest in a quiet Worcestershire churchyard. In spite of a sharp and trying temper which made him difficult to work with, Dud Dudley was one of England's greatest inventors, for it is to him that the country owes its start over the rest of the world in the use of coal for the smelting of iron.

An even greater man, whose name is now almost forgotten, lived in the same century as Dud Dudley. Andrew Yarranton, like Dud, was a Worcester iron-worker, but, unlike him, a staunch Cromwellian. He fought throughout the Civil War, and in the year 1652 opened iron-works. A little later a charge was trumped up against him, and he was thrown into prison; but the charge was proved to be false, and he was released. The next we hear of Yarranton, he was busy deepening the river Salwarp so as to give the town of Droitwich a way of sending her salt to the Severn by water.

You must remember that there were at that date no roads worth the name in England, and that canals, too, were almost unknown. Andrew Yarranton was the father, the inventor, of our canal system, and it speaks highly of

his genius that he not only proposed to connect the Thames with the Severn by water, but that the route he selected for the new canal was that actually chosen for the canal which was cut a century after his death.

Yarranton was burning with wonderful ideas of all sorts, ideas, too, that were both sound and good. It was he who first saw the need for what is called the rotation of crops. In those days the same crop would be planted on the same land year after year until the soil was exhausted. He introduced clover seed, clover being a crop which restores land which has been planted in wheat or rye. In this way he doubled the value of thousands of acres of land. He planned new docks for the city of London, but these were not built until a hundred and fifty years after his time.

You will perhaps say that these were ideas rather than inventions, but Andrew Yarranton deserves a very high place among inventors, for it was he who started the tin-plate industry which has so greatly enriched South Wales. There was plenty of tin in England, yet English industry was at so low an ebb that all plates—that is, iron-plates—were imported from Germany. Yarranton started works in the Forest of Dean, where the plates he made were soon acknowledged to be far better than those brought from Saxony.

Although he had already done more for his country than any living Englishman, Yarranton was not content. At that time the fishing industry was in the hands of the Dutch, who netted their fish within sight of English shores and sold them in English ports. Yarranton visited Holland, found out their methods, then came home and started English fisheries with English boats and fishermen.

Next, he put up a most excellent plan for the growing of flax and making linen in England, pointing out that the country would save two millions a year which was then spent on buying foreign linen. In 1677 he published a book called *England's Improvement by Land and Sea*, a

book which was certainly the most remarkable work of its kind that had appeared up to that time. It shows that the writer was one of those rare and wonderful people who sometimes are born into this world a century or more before their time. He clearly foresaw England's greatness as a manufacturing rather than an agricultural country, and writes of it as clearly as though he were possessed of the true spirit of prophecy.

But such a prophet has no honour in his own country or his own times. The shame is that Yarranton has never since his death received the honour that is his due. Samuel Smiles is, so far as I know, the only modern writer who has told Englishmen anything of their debt to this wonderful man.

I have written a little about the two greatest of early ironmasters. I must now tell you about a third, Abraham Darby by name, who was the first Englishman to use coal on a great scale for iron-smelting and the first to make iron pots in England. He was an inventor of other things as well, but I had better begin with the story of the iron pots.

In those days ranges and cooking-stoves were still inventions of the future, and in most houses cooking was done in iron pots over an open fire. All these pots were imported from abroad, for no one in England knew how to make them. Abraham Darby decided that this was a great opportunity to start a new industry in England and tried to cast pots in moulds of clay. It was no use, for they all cracked and burst, so in 1706 he went to Holland and discovered that the moulds were made not of clay but of sand.

He came home and began experimenting. He locked his workshop, and even stuffed the very keyhole so that no one should discover what he was about, and after a few trials succeeded in making perfect iron pots. For these he was granted a royal patent, which meant that he and only he was to have the privilege of making these pots for

a period of fourteen years. He moved to Coalbrookdale in Shropshire and started work.

But, clever as he was, Darby still used charcoal to smelt his iron, with the result that he soon burned up all the trees around, and, like Dud Dudley before him, was left without fuel. No wonder, for he was smelting ten tons of iron a week, and turning out twelve dozen great pots or kettles in that time. There was plenty of coal near by, and he began to make coke, which he mixed with charcoal and peat, and with this fuel carried on a very big business until in 1717 he died.

He was succeeded by his son and grandson, and by the year 1747 Coalbrookdale was celebrated for making some of the best iron in England. Large cannon were cast, and all smelting done with coal. The firm opened branches at London, Bristol, and Liverpool, and began to dig deep for coal. This deep digging was interfered with by water draining into the pits, and it was the need to get rid of this water which in the end produced the steam-pump.

In 1763 a man named Richard Reynolds came to the Coalbrookdale works as manager, and he and two of his foremen began experimenting with a new sort of furnace in which the iron was not mixed with the coal but simply heated by the flame from the fuel. They succeeded in producing what is called the 'reverberatory' furnace, in which the flame is drawn by the blast of air across a bed on which the metal is laid. The iron so produced was of very high quality and the invention a very important one.

Reynolds' second invention was equally important. At that time rough trams were used for shifting coal from the pits to the works, and these were run upon wooden rails. These rails decayed rapidly, and often broke under heavy loads. It occurred to Reynolds to use iron in place of wood; he began to make and lay down iron rails, which were found to be so great an improvement that in 1767 the whole of the old wooden

rails were taken up and replaced with iron. Reynolds may therefore fairly claim to be the inventor of the railroad, although it was not until a good many years later that the first locomotive made its appearance.

By this time Coalbrookdale had become a populous place; and an old ferry, then the only means of crossing the Severn, could no longer handle the ever-increasing traffic. A bridge was needed, and a plan for one had been got out by Abraham Darby the second, but his death interrupted the scheme. This Abraham Darby was succeeded by a son of the same name, and the young man conceived the bold idea of building an iron bridge across the river.

Some years earlier an attempt had been made to build an iron bridge in France, but the attempt failed, and a bridge of timber was constructed instead. So young Darby had nothing to encourage him. He and his foreman, Thomas Gregory, prepared the plans themselves, and in 1777 started the work. All the castings were made in the foundry, and in 1779 the bridge was opened for traffic. The fact that this bridge lasted for over a century is plain proof of its success, and for once in a way an inventor was well rewarded for his work. In 1788 the Society of Arts presented Mr Darby with a gold medal. This bridge gave its name to the town of Ironbridge.

Another great invention of the 18th century was cast steel. Steel, as you know, is iron mixed with a small amount of carbon or charcoal and tempered in a particular manner. The discovery of steel was one of the most important inventions of man, for it gave him a material so hard that it is capable of cutting and shaping almost every other substance known. Steel may be made nearly as hard as the diamond, or, on the other hand, so soft that it can be cut and bent into any shape, rolled into thin plates, or drawn into wire as fine as hair.

Steel was first made thousands of years ago and more

or less by accident. When a pure ore, such as a magnetic oxide of iron, is smelted with wood charcoal, steel is made as easily as iron and is of excellent quality. The first steel was made in the East, and the city of Damascus was the home of the finest steel blades of old days. Magnetic oxide, however, is not to be found everywhere, and it would be impossible to procure enough wood charcoal to make steel sufficient for modern needs. A century and a half ago there was already a famine in steel, and the need was felt for some means of producing it in large quantities from ordinary ore. And so we come to the memorable discovery of Benjamin Huntsman.

Huntsman was a Lincolnshire boy, born in 1704. Being of a mechanical turn of mind he set up in business as a clock-maker in Doncaster as soon as he was old enough. He became the 'wise man' of the neighbourhood; no lock was too difficult for him, and he mended not only machinery but also men. He was an excellent surgeon and a very clever oculist. It was the need for steel to make clock springs which turned his thoughts to the idea of making a better steel than that he could buy, and in 1740 he moved to Sheffield, where he began experimenting. He had to build a furnace hotter than any yet made, and a crucible which would be fit to bear this tremendous heat without collapsing.

Unfortunately Huntsman left no written records of his experiments, but we know that they went on for a very long time, and that he had failure after failure. After his death, masses of steel, all imperfect, were found buried in various places round his foundry. But in the end he succeeded—not only in making ingots of cast steel but in producing steel of a quality never since surpassed.

This steel, however, was so hard that, when he offered it to the Sheffield cutlers to make knives and razors, they refused to use it. So Huntsman began to export his steel to France, where it found a ready market. The

Sheffield cutlers were furious, and tried to stop the export of Huntsman's steel. Happily they failed, and finally they themselves were compelled to buy his steel and use it.

They next endeavoured to steal his secret, but Huntsman was too clever for them. At last, one winter night, a ragged tramp was found shivering at the door of Huntsman's foundry, and the workmen let him in to warm himself by the fire. The supposed tramp was in reality an iron-founder named Walker, who had adopted this disguise with the sole object of stealing Huntsman's secret, and in this he was successful.

But Huntsman still made the best steel, and gradually established a great business, which, when he died in 1776, he left to his son. Sheffield, the town that treated him so badly, owes its amazing wealth and prosperity to this brilliant inventor.

CHAPTER V

THE BEGINNING OF CLOCKS AND WATCHES

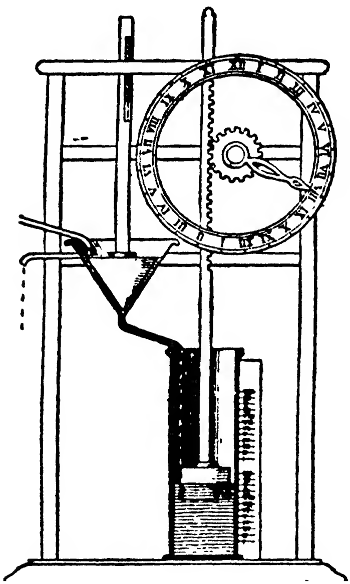
The Sun-dial—The Clepsydra—The Sand-glass—The Wholly Mechanical Clock—The First Watch—John Harrison and his Marine Chronometer—Arnold's Tiny Repeating Watch.

VERY early in the history of civilization man must have felt the need of a means of measuring time. In the far-distant Stone Age he must have soon noted that the shadows cast by familiar objects moved in a regular manner, according to the hour, and no doubt made use of this knowledge to arrange meeting-places near to such objects when the shadows should have reached a given mark.

In the heavens above he observed the god-like movement of the sun, so regular in its habits, and his own habits of waking and working and sleeping must, willy-nilly, depend upon it. Later on, as he learned to know and recognize the ordered procession of the stars, he had a clock by night as well as by day, and as the ages moved on and existence became more complicated he divided periods of time into ' moons ' and then into years, all by means of the heavenly bodies.

But this came slowly, and much more slowly came a measuring instrument. We do not hear of the sun-dial until some twenty-seven centuries ago, which is quite a brief span in the many millions of years that have passed since man first realized that ' time flies.' The sun-dial, however, was invented long before these known records and, after all, was only a step onward from the cave man's habit of using fixed objects and their shadows to mark the flight of time.

But as the sun-dial depended upon the beams of a sun which did not always shine during the day and never during the night, it could not entirely satisfy, and so man's inventive mind produced the clepsydra, or water-clock. This was but a simple contrivance, but nevertheless it was the first *time-machine*, and from it was evolved all the complicated mechanism of the modern clock. At first it was merely a jar of water with a small hole at the bottom which permitted the contents to drip out at a steady uniform rate. As the level of the water in the jar sank, the hours that had passed since the vessel was last filled were indicated.



A CLEPSYDRA

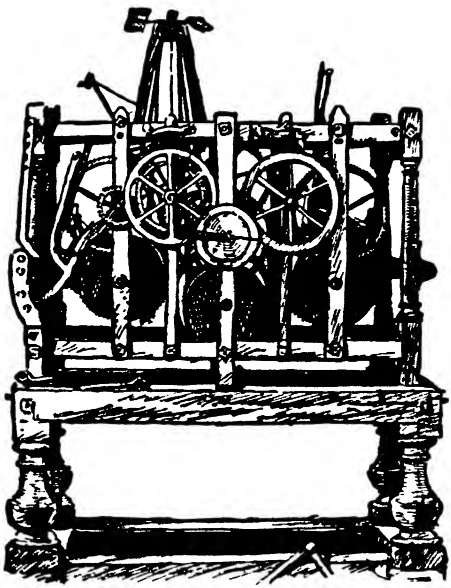
From *Time Telling through the Ages*, by permission of the Ingersoll Watch Co., Ltd.

The first water-clock was, however, but a rough-and-ready machine, and the next onward step was the addition of a smaller jar above, from which the water dripped into the larger one. As the level rose in the latter it carried up with it a float which marked the hours against an indicator upon the side of the jar.

This arrangement of twin jars gave more accurate time-keeping, but a more definite stage was reached when, about 140 B.C., a Greek of Alexandria applied a cog-wheel and a toothed rod. The latter was fixed on the float and moved the wheel as the water rose in the jar.

Clocks and Watches

We have come now, as our illustration shows, to the clock face and the moving hand indicating the hours, and the rest of the mechanism of the wholly mechanical clock was only a question of time, although more than a thousand years were to pass before clocks were set up in the great cathedrals and other public buildings of the medieval world. This was in the 13th and 14th centuries. Meantime the clepsydra died hard, for we read that it continued in common use as late as the end of the 15th century. As for the sand-glass, which was invented later than the water-clock and was useful particularly when it was difficult to keep water from freezing, it has persisted right down to our own day, and the housewife often finds it useful when boiling the breakfast egg.



OLD CLOCK OF ST GILES' CATHEDRAL, EDINBURGH

How deeply interesting are the origins of the common everyday things of our complicated life of to-day is seen in the beautifully illustrated book, *Time Telling through the Ages*,[1] which the Ingersoll Watch Company have provided as an expression of their own deep interest in their business of watch- and clock-making. This liberal contribution to the literature of the subject bears the impress of the true craftsman.

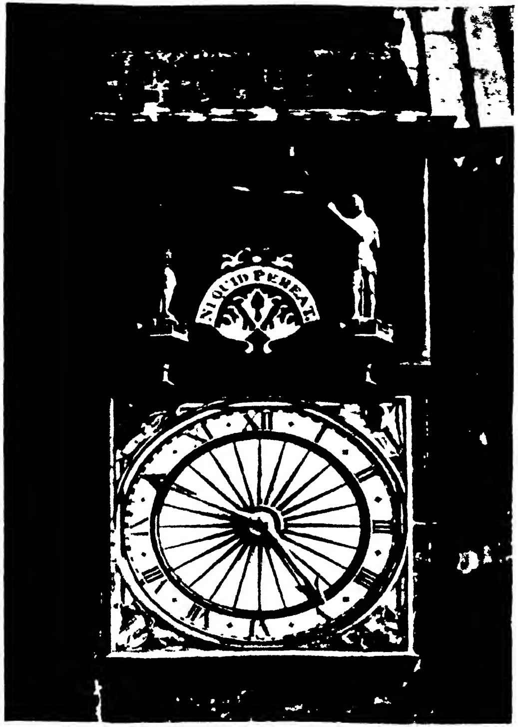
Nothing is known with certainty as to the origin of

[1] By Harry C. Brearley (Doubleday, Page & Company).

clocks such as have been generally used during modern times. Probably they date back to the 12th century, although the first known description refers to one which was sent by the Sultan of Egypt to the Emperor Frederick II in 1232. It is recorded that a clock was put up in a tower at Westminster in 1288, and about the same time one is mentioned in Canterbury Cathedral. In 1326 a clock showing various astronomical devices was erected at St Albans by the Abbot, and this probably compares with the clock in the Cathedral at Wells, of which the first known mention is in the account-roll of the Cathedral for 1392, and which is still to be seen. The interior dial plate is 6 ft. 4½ in. in diameter. On an outer circle in Old English lettering are represented the 24 hours of the day with a large gilt star as indicator; on an inner circle are shown the minutes with a small star as indicator; and a third circle gives the days of the lunar month with a crescent to indicate the moon's age. The face is very beautiful, and contains various other astronomical details. Above the dial plate are two mounted knights who revolve in opposite directions every hour when the clock strikes. Some distance away, higher up on the same wall, is a curious medieval figure of a man who strikes the hours and the quarters on bells. On the outside of the Cathedral is another dial plate of the same clock, above which two knights in armour of the 15th century strike the quarters on bells with their battle-axes. The movement has been renewed, but the ancient

MEDIEVAL FIGURE IN WELLS CATHEDRAL

a



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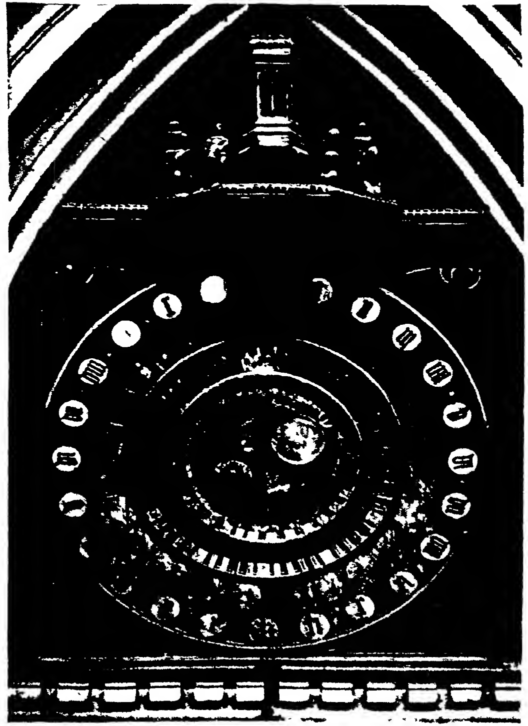

THE CLOCK AT WELLS CATHEDRAL

(a) The tower face, (b) the interior face

60

PETER HENLEIN EXHIBITING HIS WATCH

From Time Telling through the Ages

works, which are of iron, have been removed to the Mechanical Museum at South Kensington, where they may be seen in motion.

We know that watches made their appearance very early in the 16th century, for an old writer of 1511 wrote of one Peter Henlein, who "creates works that are the admiration of leading mathematicians, for out of a little iron he constructs clocks with numerous wheels, which,

A CLOCKMAKER'S SHOP IN THE 16TH CENTURY

without any impulse and in any position, indicate time for forty hours and strike, and which can be carried in the purse as well as in the pocket."

We can understand and sympathize with the enthusiasm of old Johannes Coeuleus, although we know that the cumbersome original of the dainty creations manufactured to-day were for a long period little more than toys. By Queen Elizabeth's time all wealthy people had watches, but the world had to wait until the 18th century for the chronometer, in its essence a large watch, the movement of which is made from metals which heat and cold affect

differently, so that in combination they provide a balance, or 'compensation,' as it is termed, which prevents the variation of temperature affecting its power of accurate time-keeping.

When Columbus discovered America, in the 15th century, the age of long voyages began, and at once seamen were in great need of some instrument by means of which they might work out longitude.

There was none except the log, that rough marine speedometer which, after all, gave very little help. Philip II of Spain offered the huge reward of one hundred thousand crowns, and a little later the Dutch were in the field with a promise of thirty thousand florins for such an instrument. When Charles II established Greenwich Observatory he urged upon his Astronomer Royal the desirability of satisfying this bitter need of navigators, but even with the help of the great Sir Isaac Newton nothing could be done.

Having given this explanation, I will tell you something of John Harrison, the man who made the first chronometer and so conferred a boon beyond words upon all those whose business is upon the great waters. Harrison was born at Foulby in Yorkshire in the year 1693, and began life as a carpenter. He was still a very young man when, in the year 1714, a petition was presented to Parliament by several captains in the Navy and a number of London merchants, setting forth the importance of some means by which navigators out of sight of land could find out the exact longitude.

The petition was referred to a committee, and Sir Isaac Newton giving evidence before this committee hit the nail on the head. "One [method]," he said, "is by a watch to keep time exactly; but by reason of the motion of the ship and the variation of heat and cold, wet and dry, and the difference of gravity in different latitudes, such a watch hath not yet been made." The British Government then

passed an Act offering £10,000 to anyone who should discover a method of determining the longitude within one degree or sixty miles; £15,000 if the method proved accurate within forty miles; and £20,000 if determined within thirty miles.

It was a splendid reward, for in those days £20,000 was a great fortune. It tempted even so great a man as Sir Christopher Wren, the architect of St Paul's, to make a vain effort to solve the problem. Yet where all the greatest men of science tried and failed it was the son of a poor carpenter, a boy who had barely learned to read and write, who in the end succeeded.

A real inventor is born, not made, and young Harrison from a baby not only loved to see wheels go round, but longed to know how and why they went. When only a tiny lad of six he fell ill with smallpox, the worst scourge of the country at that period, and while he lay hot and parched with the terrible fever a going watch placed in his small hands quieted him and filled him with delight.

Growing older he became a carpenter, like his father, but still he loved his wheels, and began experiments in clock-making. A large clock made almost entirely of wood by Harrison when only twenty-two years old is still preserved in the South Kensington Museum. Later Harrison turned entirely to clock-making, and worked desperately hard. A kind clergyman lent him books, and soon he was not only equal to the clock-makers of his time, but had gone beyond them.

Presently, in 1726, came his great invention, the compensation pendulum. Since all metals contract with cold and expand with heat the ordinary pendulum grows longer in hot weather and shorter in cold, so that the clock of which it forms a part is not dependable. But all metals do not alter equally, and Harrison noticed this and made a pendulum like a gridiron of alternate bars of steel and brass so arranged that the bars which expanded most were

countered by those which had least expansion. One of these clocks which he kept by him did not vary so much as one minute in ten years.

Harrison began to think much of the great prize, which, although it had been on offer for fourteen years, had never yet been claimed, and in 1728 went up to London to show his drawings to Dr Halley, the Astronomer Royal. The astronomer sent him to George Graham, the greatest of London's clock-makers, who generously praised his work, but said that he had better go home and make his machine before applying to the Board of Longitude.

Now began a time of terrible trial for the plucky clock-maker. He had to make a living while he worked ; he had to make his own tools and to teach himself to work in brass and other metals in which he had had little experience. No one backed him with money, and he was obliged to earn all that he needed for the purchase of tools and materials. All sorts of difficulties arose. For instance, in an ordinary watch as then made, time was lost during the process of winding. Harrison inserted a secondary spring which kept the works going while the winding up was being done. It took him seven years to make his first chronometer, and this, set in a special frame, was tried on a seagoing barge and found to work well.

In 1735 Harrison went to London again and submitted his chronometer to the Royal Society, who examined it with great interest and gave him a certificate stating that the principles of his invention promised a great degree of exactness. The chronometer was then shown to the Admiralty and given a trial on the *Centurion*, a man-of-war. Harrison went with it and came back in another warship, the *Orford*. On the way back, when the ship first sighted land, the captain and officers thought that this land was Start Point, but Harrison, working by his chronometer, declared that it was the Lizard. Harrison was right ; the navigators were no less than *ninety* miles out of their

reckoning. The captain gave Harrison a letter describing the amazing success of his chronometer, and Harrison at once went before the Board of Longitude, no doubt fully expecting that he would receive the £20,000. They voted him £500 for expenses toward making a new and less cumbersome instrument, of which money only half was paid down.

This new time-keeper Harrison completed in 1739, yet not satisfied with it made a third and still smaller machine. But various difficulties arose, especially in the tempering of springs, and it was not until 1749 that Harrison completed a chronometer which fully satisfied him. During all these years he had lived and worked on two grants of £500 each.

The Royal Society, who, as on the previous occasion, fourteen years earlier, were the first to see the new chronometer, were delighted with it and awarded Harrison the highest prize in their power, the Gold Medal. In his speech, when making the presentation, the President spoke of Harrison as the "most modest person he had ever known," and of his chronometer as working with "a degree of exactness that is astonishing, even stupendous, considering the immense number of difficulties which the author of this invention must have had to encounter."

Now you might surely suppose that the Board of Longitude would have paid over the well-earned £20,000. But not a bit of it! It was not until the year 1761 that the third time-keeper was given a trial aboard the *Dorsetshire* bound for Jamaica. Harrison's son William went with it, and came back in the *Deptford*. The chronometer worked to perfection and corrected the log of the *Deptford* to the extent of no less than three degrees of longitude. After all this voyaging the chronometer, when tested on return, was found to be correct within five seconds.

Still poor Harrison could not get his money. For thirty-five years he had worked as few men have worked,

and had conferred on his nation one of the greatest benefits that any one man has conferred on his country, yet the Board would not certify that he had won the prize. Harrison petitioned Parliament, and an Act was passed giving the inventor £5000. Still the wretched Board haggled disgracefully. They paid him a small sum on account, and two more years dragged by. In September 1764 Harrison managed to get another thousand pounds, and in the following year the Board passed a resolution that the inventor was entitled to the whole reward as offered in the Act of 1714. Yet still it was not paid over.

Other countries were not so stingy. The King of Sardinia ordered four of Harrison's chronometers, paying him a thousand pounds apiece. Harrison was now seventy-three, his eyesight was failing, yet still he struggled for his just dues. He wrote the Board the stiffest letter those gentlemen had ever received, and there followed a stormy interview. But at last half the money was forthcoming, with a promise of the other half as soon as his other chronometers had been tested.

The test was made by no less a person than the great Captain Cook in his memorable voyage round the world,[1] and in 1773, forty-five years after his first experiments, John Harrison received the remainder of his hard-earned money. He died three years later, at the age of eighty-three; his tombstone may still be seen in Hampstead Parish Churchyard.

Harrison's great successor in the art of clock- and watch-making was John Arnold. Harrison's chronometer was so complex that its price was £400. Arnold decided that something smaller could be made, and set himself to work. In 1776 he invented the cylindrical spring and the compensation balance, and applied these to a

[1] See *The Book of Discovery*, chaps. xxiv–xxvi.

new chronometer. Arnold was much better treated than Harrison, for the Government awarded him a sum of £3000 down.

Arnold was also the inventor of the method of ' jewelling ' watches and clocks; that is, he used precious stones for those parts which have to withstand most wear. Jewels, such as rubies, are far harder than even the best steel, and so will last longer than metal bearings and give better results. In 1771 Arnold applied ruby ' pallets ' to the great astronomical clock which had been made by Graham for Greenwich Observatory.

Arnold was a wonderful workman, and made the smallest repeating watch ever known. It was made for King George III, and presented to him on his birthday, June 4, 1764.

It was only six-tenths of an inch in diameter and the weight of a sixpence, yet it kept perfect time and repeated the hours, half-hours, and quarters with a tiny tinkling chime. The King was delighted with it, and made Arnold a present of five hundred guineas. The Czar of Russia saw the watch and offered Arnold a thousand guineas to make another like it, but Arnold reluctantly refused, saying that his eyes would not stand the strain.

Chronometers continued to be improved, and in 1830 two were made for Greenwich Observatory by Charles Frodsham. They were observed daily for twelve months, and in a certificate granted to their maker it was stated that one made an extreme daily variation of the eighty-six-hundredth of a second, the other of fifty-seven-hundredths only. An amazing record and one extremely creditable to British watchmakers.

CHAPTER VI

THE COMING OF STEAM

Watt's Predecessors—The Great Invention of James Watt, and how it led to further Discoveries—The First Road Locomotive—Steamships—The Birth of the Railway.

THE steam-engine invented by the Marquis of Worcester raised a column of water to a height of forty feet and was on view at Vauxhall from 1663 to 1670. But so far as I am aware, this engine was never used for pumping water out of a well nor for any other such purpose. In 1688 a Frenchman, Denis Papin, built a model engine in which a piston was moved in a cylinder by the expansive force of steam. Papin fitted this engine into a boat; but the river boatmen, being afraid that, if successful, it would ruin their business, seized and destroyed it.

It was a Devonshire blacksmith who first used steam to aid man in his work. Thomas Newcomen was born at Dartmouth in 1663, and in the year 1705 he and a glazier named Cawley, together with Savery, who was manager of a Cornish tin-mine, obtained a patent for a steam-pump which a few years later was being used for pumping water out of the deep Cornish mines. This engine had no piston, was very slow in working, and wasted four-fifths of the steam at every stroke. Yet in spite of all this it did good work, and for nearly seventy years was the only steam-pumping engine in use.

The first great improvement in Newcomen's steam-pump was the invention of a small boy. The engine, as first made, required an attendant who had to open and shut two taps in turn, one to introduce steam into the

cylinder, the other to throw in a dash of cold water for the purpose of condensing the steam. The work, being so simple, was generally done by a boy.

One day a lad named Humphrey Potter was told off to attend to the taps, and as he stood there horribly bored by the monotonous job of turning first one tap and then another, he could see his chums having a great game in the field below. He simply longed to go and join them, but knew too well what a licking he would get if he deserted his post. He stood glaring at the hated taps, and then suddenly he saw something which he had seen a hundred times before, but never noticed. Of the two taps one had to be opened just as the beam of the engine had dropped to its lowest point on one side, and shut exactly as the beam rose to its highest point on the other side. The management of the second tap was the exact reverse of the first.

Humphrey, if young, was quick-witted, and through his brain flashed a brilliant idea. Why not make the beam do the work? Out came a coil of string from his pocket, and he started in to experiment. He fastened cords to the handles of the taps, tying the loose ends to the beam itself. In a very short time he had solved the problem, and to his intense delight saw that the engine was doing its own work. He at once rushed off to find his friends.

We have no record of what the manager said when he found the engine running by itself and no Humphrey in sight, but at any rate he had sense enough to see that the boy had made a big discovery, and at once fixed rods instead of strings to the beams. Humphrey's invention was soon applied to all the other steam-pumps in existence.

After that it was not until the year 1763 that any great improvement was made in the steam-engine, and this was the work of the famous James Watt. Watt was born at Greenock on the Clyde in 1736, and was a lover of machinery from a child. Various stories are

told of how his great idea concerning the utilization of the power of steam was born. One of these is illustrated in a fine picture by Marcus Stone, R.A. We see Watt as a small boy at his parents' table apparently toying idly with a spoon upon the spout of a kettle. According to this story, the boy was reproved by his father for not interesting himself in something more useful. Whether the story be true or not, it is of such stuff that the dreams of the inventor are made, and Watt was more than merely amused by noticing that the steam from the kettle could lift a weight placed upon it. He must have asked himself the great question "Why?" and in trying to answer it was led to see that the heat of the fire was turning the water into something which took up more room than the water, something very hot and very elastic. You can think of him making experiments, putting a weight upon the kettle lid to see what happened, perhaps trying to stop the spout. No doubt he burned his fingers, no doubt he got well scalded; but the boy kept on watching steam, thinking steam, until by degrees he came to a point when he resolved to capture and make use of this force.

When Watt grew up he became an instrument-maker at Glasgow University, and it was here that a model of Newcomen's steam-pump was brought to him one day for repair. This engine, as I have pointed out, wasted steam in shocking fashion, for since at every stroke *cold* water was driven into the cylinder to condense the steam, most of the energy of each fresh inrush of steam was wasted in re-heating the cylinder. Watt resolved to find some way of preventing this waste, and for two whole years spent nearly all his spare time in puzzling out the problem.

Now it is a curious fact that if you struggle long enough and hard enough to solve a problem the solution usually comes like a flash of lightning. This is exactly what happened in Watt's case. As he was taking a walk one

WATT'S FIRST EXPERIMENT
Marcus Stone R.A.

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SYMONS STOOD WATCHING WITH EAGER EYES"

fine Sunday in 1765, suddenly, as he says himself, "the whole thing was arranged in my mind." His great idea was to connect to the working cylinder a vessel into which the steam could be exhausted for condensation so that it would be possible to keep the cylinder itself constantly hot.

Next morning he started to make a model, and when finished, rough as it was, he was overjoyed to find that it would work. A certain Dr Roebuck put up money for Watt to build a working model, and presently a patent was granted. But, as has been the case with many inventors, this was not the end of his troubles, for when he came to build a big engine his workmen made such a mess of it that it was not very successful. Then Dr Roebuck lost all his money, and Watt was left penniless and in debt.

But brighter days were in store. Matthew Boulton of Birmingham saw the model, and realized the value of the new invention. He was able to find money, and with this help Watt produced his first modern, double-acting steam-engine. It had a governor to control its speed and a device to make the piston turn a fly-wheel. I am happy to say that the firm of Boulton & Watt flourished greatly and that both partners made fortunes.

It is truly said that one invention invariably leads to another, and once the steam-engine had arrived it could only be a question of time before it was adapted not merely, in its stationary form, for driving machinery, but for purposes of locomotion. Numbers of people believed that both ships and carriages would sooner or later be driven by the power of steam, but the three men to whom the world owes these inventions are William Murdoch, Robert Fulton, and George Stephenson.

William Murdoch was the son of an Ayrshire millwright, who settled at Birmingham and went into the works of Messrs Boulton & Watt. His employers thought so highly of him that they sent him to take charge of their

new winding-engines at Redruth in Cornwall at a salary of £1000 a year, an immense one in those days.

In his spare time Murdoch amused himself by building a small road locomotive which was really the first motor car. He finished this in the year 1784, and decided to try it on a piece of level road about a mile out of the town. He waited until night to make the experiment, then lit the lamp under the boiler. Steam was generated much more rapidly than he had supposed possible, with the result that suddenly off went the engine, so fast that Murdoch, though he followed as hard as he could run, could not catch up. Presently he heard a great outcry, and a few moments later came upon the village clergyman in the hedge, his teeth chattering, and shaking all over with terror.

"It was the evil one—the evil one himself!" groaned the parson. The poor man had met Murdoch's new monster roaring along and puffing out fire, and was fully convinced that he had encountered the father of all evil.

Murdoch's road-engine went up a hill almost as well as it travelled on the level, and from it was afterward evolved the steam coach which was so great a success some eighty or ninety years ago. It is sad to think that had it not been for short-sighted laws made by the English Parliament, the world might have had motor cars fifty or sixty years before they actually came into use. Murdoch's model locomotive was exhibited in London before the Institute of Mechanical Engineers in 1850, sixty-six years after the date of its construction.

Oddly enough it was also in Cornwall that another inventor produced a road locomotive. This was Richard Trevithick of Camborne, who, in the year 1801, ran his crude but powerful machine up Beacon Hill, Camborne. Trevithick deserves all credit for his ingenuity, and there is to-day a window in Westminster Abbey to his memory.

The inventor of the modern steamboat was an American,

Robert Fulton by name. Paddle-boats worked by man- or horse-power had already been tried without success, and as early as the 17th century David Ramsay, Dr Grant, and the Marquis of Worcester had each suggested the use of steam to drive ships. The Frenchman, Papin, actually made a steamboat, and in 1736 Jonathan Hulls, a Gloucestershire man, built a large boat which he tried to drive on the River Avon by means of a Newcomen engine. This was not a success, and the following doggerel lines commemorate his failure:

> Jonathan Hull
> With his paper skull
> Tried hard to make a machine
> That should go against wind and tide.
> But he, like an ass,
> Couldn't bring it to pass,
> So at last was ashamed to be seen.

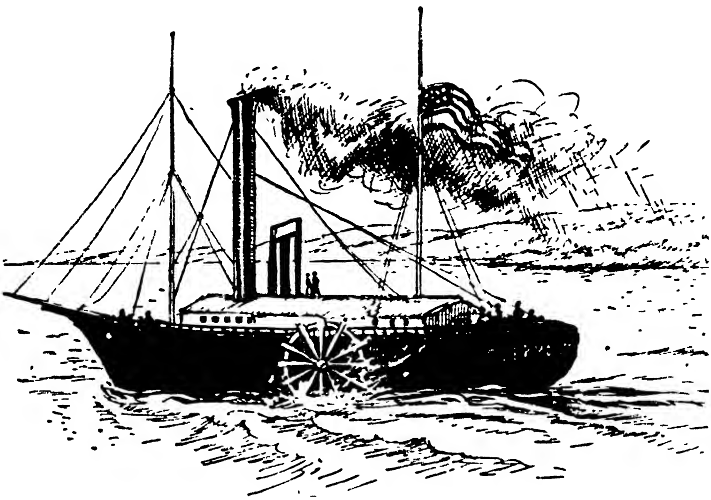
So it was left for Robert Fulton to build the first real steamship. Fulton was a native of the town of Lancaster in Pennsylvania, and was known as 'Quicksilver Bob.' He was an architect, a painter, and, above all, an inventor.

In 1786 he went to England, and there invented a new machine for spinning flax, another for twisting hemp rope, and a third, a great shovel for scooping up earth in making canals. It was his friend the Earl of Stanhope who started him upon propelling boats by steam. Fulton went to Birmingham, and after studying Watt's double-acting steam-engine had a large model built to his own order and shipped to America. He himself followed, and on arrival entered into partnership with Chancellor Livingstone, who provided money for the building of the *Clermont*, a good-sized craft of one hundred and fifty tons burden. In it was Fulton's English-made engine, which was fitted to drive paddle-wheels.

On August 17, 1807, Fulton went aboard at New York, started up his engine, and began his historic journey to

Albany, the capital of New York State. The excitement was terrific at sight of this vessel, the first in the world's history to defy wind and tide. Unlike that of most inventors, Fulton's success was instant and amazing, and before he died, at the early age of fifty-one, he had built seventeen steamers which plied from town to town up and down the great Hudson River.

Fulton has another claim to fame. It was he who built



THE "CLERMONT"

the first submarine boat. This he constructed in France before his invention of the steamboat, and tried in the harbour of Brest in July 1801. He descended to a depth of twenty-five feet below the surface, and on a second trial travelled for five hundred yards under water, using compressed air to enable himself and his crew to breathe. On another occasion he stayed under water for no less than one hour and forty minutes.

If the great Napoleon had made the most of Robert Fulton's inventions, Waterloo might never have been fought, and the whole history of the modern world might

have been changed. But Napoleon disliked the brilliant American, and refused to allow the French Academy of Sciences to investigate his new devices. So Fulton returned to England, with the results which I have already described.

A very great man was Robert Fulton and, with his friend the great Benjamin Franklin, the first of the long series of brilliant inventors produced by the New World.

Some years before Fulton's great success with the *Clermont*—namely, on October 14, 1788—a little steamer engined by a man named Symington had been tried in Scotland with some success. A second, called the *Charlotte Dundas*, was built and used on the Forth and Clyde Canal for towing barges; but the canal owners complained that the swell damaged the banks, the boat was withdrawn from use, and her inventor died in poverty. Fulton, it should be mentioned, had seen the *Charlotte Dundas* and got some of his ideas from her.

As soon as Fulton's *Clermont* was proved a success the building of similar craft was started in Great Britain, and in 1812 one constructed by Andrew Bell ran on the Clyde. Three years later the Thames saw her first steamer, the *Richmond Packet*, which plied between London and Richmond. In the same year, 1815, a steamer named the *Argyle* came round to London from the Clyde, and in spite of high winds and rough seas made the voyage of seven hundred miles in just over five days.

All these early steamers were driven by paddles, but the idea of the screw as a means of propulsion is much older than is generally supposed. So long ago as 1770 James Watt wrote to his friend Dr Small a letter in which he says: "Have you ever considered a spiral oar for the purpose of propulsion, or are you for two wheels?" Before the end of the 18th century several patents were taken out for screw propellers, one by Joseph Brainak of lock fame, another by an Austrian named Joseph Ressel,

a third by W. Lyttleton, in 1794. But nothing practical was done in this direction until a Hythe man, Francis Pettitt Smith, began to experiment.

'Screw-Smith,' as he was afterward called, was a farmer who grazed sheep on Romney Marshes, and how and why he became an inventor is one of those puzzles that one is always finding when studying the subject of inventors and inventing. His first model was made in 1834, when Smith was twenty-six years old. The screw in this little boat was worked by a powerful spring.

Two years later he took out a patent for propelling vessels by means of a screw revolving beneath the water at the stern, and in the autumn of that year a small steam vessel of ten tons with an engine of six horse-power was built to test Smith's invention. The screw was made of wood and had two whole turns. The little vessel was tried on the Thames, and ran well but slowly. As she went up the river the screw struck some floating timber and was broken in halves, when, to every one's amazement, she shot forward more rapidly than before. Smith took the hint, and fitted a new screw with only one turn, with which his vessel worked much better. The modern screw propeller with which all ships are fitted is of this one-turn shape.

A little later Captain Ericsson, the famous Swedish inventor, built the *Francis B. Ogden*, fitted with two, or twin, screws in which he took the Lords of the British Admiralty for a trial trip. Her speed was no less than ten miles an hour, and she was extremely seaworthy. The Sea Lords were not convinced that the screw was superior to the paddle, and many years passed before British war vessels were fitted with screws. So Ericsson went to the United States, where he found his talents better appreciated. Years later he built the famous *Monitor*, the first real ironclad, and he also invented the first torpedo boat. He lived to be more than eighty years of age.

Screw-Smith stuck to his guns, or rather his screw, and

in 1839 produced the *Archimedes*, a wooden vessel of 237 tons fitted with his patent screw. The builders said she could not do more than five knots, but when tried it was found that her speed was no less than nine and a half knots. In 1840 she made a tour of all the principal ports of Great Britain, and it was through seeing and examining the *Archimedes* that the great engineer Brunel, son of the inventor we shall meet in Chapter VIII, had his fine ship, the *Great Britain*, fitted with a screw. The *Great Britain*, built in 1843, was 274 feet in length, and much the largest steamer which had been launched up to that date.

The first British warship to be fitted with a screw was the *Rattler*, of 888 tons. Tried against the *Alecto*, a paddle-ship of similar power, the *Rattler* simply ran away.

Smith ended by forcing his invention on the shipping world; yet in 1856, when his patent expired, he had not only made nothing, but had spent every penny of his own money. It is pleasant to be able to tell you that he was not left to starve, like so many other inventors. The Civil Engineers subscribed £2000 as a testimonial, the Queen gave him a Civil List pension of £200 a year, he was made curator of the Patent Museum at South Kensington, and in 1871, three years before he died, was knighted.

Having told you something about the first road locomotive and the first steamships, I must now speak of the third great invention which arose from Watt's perfected steam-engine. George Stephenson was born at Wylam, a village near Newcastle, on June 9, 1781. His father was a fireman in a colliery. George was a sturdy, vigorous youngster, and as soon as he was old enough became 'picker' in the colliery; that is, he picked the coal from the stones and dross, working all day for a few pence. In his spare time he learned to read and write and studied hard. He rose to be fireman, then engine-man, and presently was given the job at Willington Quay of managing a fixed engine which drew coal trucks up a

hill. Here he invented a way of making the full waggons running down an incline pull up the empty ones by their weight.

Rough locomotive engines were already at work, hauling coal at the Killingworth Colliery. These had been built by a Mr Blackett on the model of a road-engine produced by the Cornish inventor, Trevithick. Stephenson frequently examined these and also another primitive locomotive known as Blenkinsop's Leeds engine, which drew a chain of colliery trucks at the modest pace of three miles an hour.

Stephenson made up his mind that he could build something better than either of these engines, and in 1813 went to the owners of the mine and told them he had plans for a new travelling engine. The principal partner, Lord Ravensworth, was so interested that he agreed to supply means for the experiment, and Stephenson built his first engine in the workshops at the West Moor mine.

This engine had two vertical cylinders the power of which was carried by spur wheels to the driving wheels. It was called the 'Blutcher,' and when tried was found capable of pulling eight loaded waggons up a slight slope at the rate of four miles an hour. The chief novelty about this engine was that the wheels were smooth like those of a modern engine. All the locomotives built before the 'Blutcher' had cogged wheels.

But Stephenson's first engine had no springs and jolted so badly that it damaged the rails and knocked itself to pieces. Also the steam escaped with such a hissing that it frightened horses. Stephenson saw its faults and set to work to correct them, and the first thing he did was to carry the waste steam into the chimney. This, he found, increased the draught and improved the combustion. The second engine was much better than the first, yet, curiously enough, very few people took much notice of it.

Stephenson with his son Robert went on building new

engines, but these were only used in collieries. In 1822 the owners of the Hetton Collieries opened a railway eight miles long and had five of Stephenson's engines for use upon it. But the line was only for hauling coal. Meantime, Mr Edward Pease of Darlington had made a plan to build a railway from Stockton to Darlington. Stephenson went to see him, and Pease went to see Stephenson's engines, and was so interested, both in the engines and their

STEPHENSON'S RAILWAY TRAIN

builder, that he gave him the job of building the railway. All the mail-coach owners were against the plan, and fought it desperately, but Stephenson carried on, and on September 27, 1825, the new line was opened for traffic.

A newspaper of the time gives the following account: "The signal being given, the engine started off with the immense train of carriages, and such was its velocity that the speed was in some parts twelve miles an hour. At that time the number of passengers was computed to be four hundred and fifty, which, together with the coals, merchandize, and carriages, would amount to nearly ninety tons."

This railway was originally meant to carry goods only,

but later Stephenson built a passenger coach called 'The Experiment,' and within a few weeks this was packed at every journey. The Stockton and Darlington was the first real railway and Stephenson's engines the first real locomotives. It was thus that the way was paved for the line between Liverpool and Manchester and for Stephenson's famous 'Rocket,' which won the historic prize for the best locomotive. I should like to tell you of Stephenson's triumph when he himself drove the first train on the new Liverpool and Manchester Railway on September 15, 1830. But such a story belongs to engineering rather than invention.

CHAPTER VII

GAS-LIGHTING AND THE SAFETY LAMP

William Murdoch lights his House—He brings Gas to London—Sir Humphry Davy and the Safety Lamp.

WILLIAM MURDOCH, whom I have already mentioned as one of the first inventors of a steam-engine for travelling on the roads, is best known as the inventor of lighting by coal-gas. Murdoch was a born inventor, a tremendous worker, and —fortunately for himself—a very strong man. When he first went to Cornwall for the firm of Boulton & Watt the ignorant miners hated steam-engines, and one day, soon after his arrival in Cornwall, four or five strapping mine-captains (overseers) came into his engine-room at Chacewath and began to sneer at and bully him.

Murdoch flung off his coat, rolled up his sleeves, and said to the biggest of the men, " I'll take you first." He hammered him properly, and the rest looked on. When the fight was over and the Cornishman lay flat on the floor they merely grinned. " Thou be'est a proper man," said one; and after that not only did the bullying cease, but Murdoch became immensely popular.

Murdoch worked all day and often most of the night on his firm's engines. When any went wrong it was always he who was sent for post-haste to do the repairs, and how he found time for his inventions is something of a miracle. In 1791 he took out a patent for a sort of paint to prevent ships' bottoms from being fouled by weed and shellfish, and about the same time patented a pneumatic lift which was to be worked by compressed air. He also invented a cast-iron cement made of iron and sal ammoniac. He

used compressed air to ring the bells in his house, and when the great novelist Sir Walter Scott saw them he insisted upon having all his bells at Abbotsford fitted up in similar fashion.

Murdoch was always devising little 'dodges' for his own house, and it was from such a small invention that the discovery of how to utilize coal-gas came about.

Years before his time it had been noticed that jets of natural gas were found in coal-mines. A writer in *Philosophical Transactions* somewhere about the year 1733 speaks of an experiment made in sinking a pit near Whitehaven. A bladder was filled with gas from one of these natural jets, tied up, and left for some days. Then the contents, pressed gently through a small jet, were directed into the flame of a candle and found to burn with a strong flame. Six years later Dr John Clayton actually manufactured this gas—'spirit of coal,' he called it—from coal placed in a small retort. Other similar experiments were made in 1767 and 1784, but only as a sort of scientific amusement, and it was not until Murdoch's time that it occurred to anyone to make real use of coal-gas.

In those days inventors usually worked behind locked doors; indeed, many of them do so still, and one day Murdoch was very busy in his closed workshop at Camborne in company with his friend Dr Boaze. Half a dozen boys who were keen to find out what was going on were hanging about outside when suddenly the door opened and Murdoch himself came out. He laid a perfectly friendly hand on the shoulder of the nearest boy, whose name was William Symons. "Run down to the shop, Bill," he said, "and get me a thimble."

Symons was off like a shot, but when he came back with the thimble he pretended to have lost it. While he searched in his pocket he took the opportunity of slipping in at the door, and there he stood watching with eager eyes. On the fire was a heavy kettle filled with coal, to

the spout of which was attached a tube. When Symons at last produced the thimble, Murdoch bored a small hole in it and then fastened it to the end of the tube. Then he applied a light to the thimble, and a long jet of burning gas rushed out.

In 1792 Murdoch fitted up a retort in his house, piped the place, and lighted every room with coal-gas. He also made himself a gas lantern with a container for the gas, and used this when he walked across the moors at night.

Other people were experimenting with coal-gas, and in 1801 it was proposed to light the streets of Paris in this manner. The only objection was that no one in Paris knew quite how to do it. Murdoch, however, was at work, and in 1802 he illuminated the front of Boulton & Watt's works in Soho with gas. People came from all parts of London to stare at the new illumination, for at that date, little more than a century ago, the dirty, narrow streets were lighted only with occasional dingy oil lamps or with flaring, smoky torches. Link-boys, as they were called, always accompanied wealthy folk when going out to any evening entertainment.

Boulton & Watt built new plants for making gas retorts and pipes, and began to fit up many of the big cotton mills in the North with the new light. Yet the people at large did not take to it. Even so great a man as Sir Humphry Davy, inventor of the safety lamp, laughed at gas-lighting, and asked Murdoch if he meant to make the dome of St Paul's into a gasometer. Another well-known professor declared that they might as well light London "with a slice of the Moon."

Murdoch, however, went steadily on with his work, and in 1808 read a paper before the Royal Society. Modest as he was, he did say this much: "I believe I may claim both the first idea of applying and the first application of this gas to economical purposes." The Society awarded him their Gold Medal for his work.

Clifton, where he cured by making his patients breathe medicated air.

It was of this hospital that young Humphry Davy soon became superintendent, and here the young man met many celebrated people, including the poets Southey and Coleridge and the Earl of Durham. He began experiments with gases, and more than once nearly killed himself by breathing poisonous mixtures. He discovered nitrous oxide, or laughing-gas, and in 1799 published *Researches, Chemical and Philosophical,* a book which made him a great reputation and led to his appointment, at the age of only twenty-two, as lecturer to the Royal Institute in London.

He was very good-looking, he had fine manners, he dressed well, had a delightful smile and a most taking manner. His lecture-room was always crowded, and for two hours on end he could hold his audience in delighted silence. He was the most popular young man in London, yet was never spoiled, for his laboratory was the best equipped in London, which, however, takes nothing from the credit of his splendid discoveries. He began by electrolyzing water; then he discovered the two metals potassium and sodium. This he did by means of electricity, and when the little balls of shining molten metal appeared he was so delighted that he shouted and danced round the room.

These were discoveries, but Davy went on to make inventions. It was he who produced the first electric light the world had ever seen. This he did with a battery of two thousand cells paid for by his admirers. I could fill this book with the story of the brilliant young chemist's endless discoveries, among which were the elements barium, strontium, calcium, and magnesium. He also did great things for the farmer by his work in agricultural chemistry. In 1812 he received the honour of knighthood, and also was married.

Gas-lighting and the Safety Lamp

About this time one of the greatest honours possible was conferred upon him. England and France were at war, yet Sir Humphry Davy was allowed to visit France, and was received with the greatest honour by scientific folk in Paris.

In the year 1815 came the invention for which Davy's name will always be remembered—that of the safety lamp for collieries. The dreadful explosions which were formerly so common in coal-mines and which still occur at times are caused by methane or marsh-gas (called by miners 'fire-damp') leaking out of the coal seams. Mixed with air in the proportion of one part of fire-damp to ten of air, methane becomes highly explosive, and the danger is made worse by the fine coal dust suspended in the mine.

DAVY'S SAFETY LAMP

Before Davy's invention, several attempts had been made to construct a safety lantern. Dr Clanny of Sunderland made one, but it was unfit for ordinary use; George Stephenson invented one that was rather better and was used a good deal under the name of the 'Geordie.' But Sir Humphry Davy was the first to apply scientific knowledge to the problem, and he discovered that gauze of a certain degree of fineness placed round a flame arrests the passage of that flame to an explosive. He laid down that the apertures in the gauze must not be more than one-twenty-second of an inch in diameter, and that the wire itself should be from one-fortieth to one-sixtieth of an inch in thickness. When a lamp so protected is brought to a part of the pit which is dangerous the flame enlarges and turns pale. This gives warning of the presence of gas, and the miner can either put his lamp out by plunging it in a bucket of water or hurry away to a safer place.

The Davy lamp was not perfect, for its light was poor

and in a strong draught of air it was not safe. Yet it was an immense improvement on anything that had gone before, and its principle is still preserved in other safety lamps which have since been invented. It has been the means of saving countless lives and millions of pounds' worth of property, and its invention was one of the greatest boons ever conferred by any one man, not only on his own country, but on the civilized world.

ELECTRIC SAFETY LAMP

For his work on this lamp Sir Humphry was presented with a testimonial of fifteen hundred pounds and a service of plate. He was also created a baronet. In 1825 he fell ill from a paralytic attack. He went abroad to try to get well, but died in Geneva in 1829. The Swiss gave him a magnificent public funeral. There is a tablet to his memory in Westminster Abbey and a statue in Penzance. Of him it was said after his death: "He was not only one of the greatest but also one of the most amiable and benevolent of men."

One of the most recent of safety lamps is the electric lamp invented by Mr Edison shortly before the War. It is carried by the miner as an attachment to the front of his cap, and the case in which the battery is carried is secured by a belt to his back. It is impossible for the miner to cause a spark by tampering with the connexion; the lamp is handed to him fully charged and with the steel battery case padlocked and proof against rough handling. For this invention Mr Edison received the Rathenau medal—the greatest honour at the disposal of the American Museum of Safety.

CHAPTER VIII

LOCKS AND BLOCKS

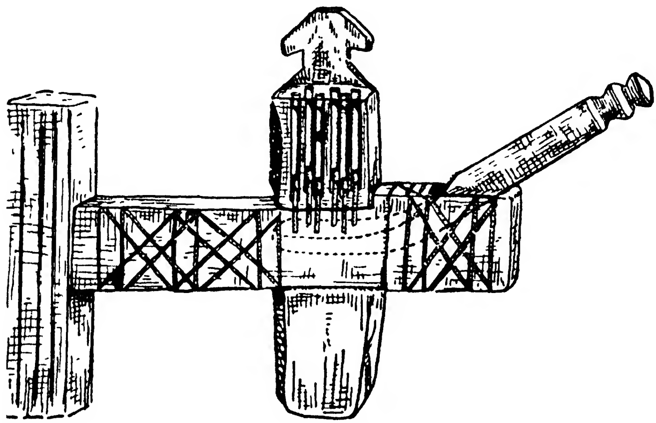
Bramah's Burglar-defying Lock—His Invention of the Hydraulic Ram—Henry Maudslay and the Slide-rests for Lathes—Brunel's Machine for making Pulley-blocks.

NEARLY all the great inventors have risen from the humblest ranks of life. Watt, Murdoch, and Harrison are notable examples of self-educated men. Joseph Bramah, one of the first of the great modern lock-makers and an inventor of many other useful and interesting devices, was the son of a small farmer who lived near Barnsley in Yorkshire. Born in 1748, he was the eldest of five children, and after the most elementary education at a cheap little school his father set him to ploughing and work on the farm. Like other inventors he showed his ability at a very early age, for he began by making a violin, which he carved out of a solid block of wood. The tools he used were made for him out of old files and scraps of metal by the village blacksmith. Yet Joseph would probably have remained a farm hand but for an accident.

When sixteen he broke one ankle so badly that he was lamed for life and could no longer follow the plough. So his father apprenticed him to the village carpenter, whose name was Allott, and Joseph soon became a first-rate craftsman in wood. An apprentice in those days got no pay, but Joseph managed to get a little pocket-money by making violins in his spare time. One he sold for as much as three guineas, and when his time was up he had money enough to take him to London. Lame as he was, he tramped the whole distance and

found work with a cabinet-maker. When he had saved some money he set up a business of his own in a little shop in Denmark Street, St Giles, and we next hear of him as patenting an improved water-cock, which soon had a good sale.

He then started the manufacture of pumps, and was able to send for his old friend, the village blacksmith, to take charge of his smithy. Attempts were made to pirate his tap, but Bramah defeated them, and began



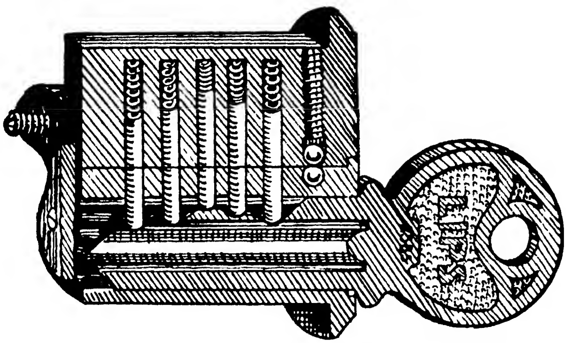
ANCIENT WOODEN LOCK AND KEY FROM KHORSABAD (MUCH REDUCED)

to do so well that he was able to start upon an idea which had been growing upon him for some years—namely, a lock better than any made up to that time.

The most ancient key lock known is described by Joseph Bonomi in his book, *Nineveh and its Palaces.* Bonomi had observed this lock on a door in a palace at Khorsabad in Mesopotamia. " At the end of the hall," he writes, " was a massive single-leaf door, closing an exit. It was locked by a heavy wooden lock of the type which may still be seen in the East. The key, also of wood, was of such dimensions that it had to be carried on the shoulder. This key operates a wooden bar, which slides from right to left and enters a square mortise in the wall."

By the courtesy of Lips Limited I am able to give an illustration of this very lock, a model of which is in their collection, and I include a drawing of one of the firm's own locks, which depends upon the same ancient principle of the sliding vertical pins.

The upright bar with ornamented top was fastened to the inner side of the door and a sliding horizontal bar fitted into a deep groove cut in its face. The end of this bar was pushed into a slot in one of the door-posts, and was then locked by the falling of a number of loosely

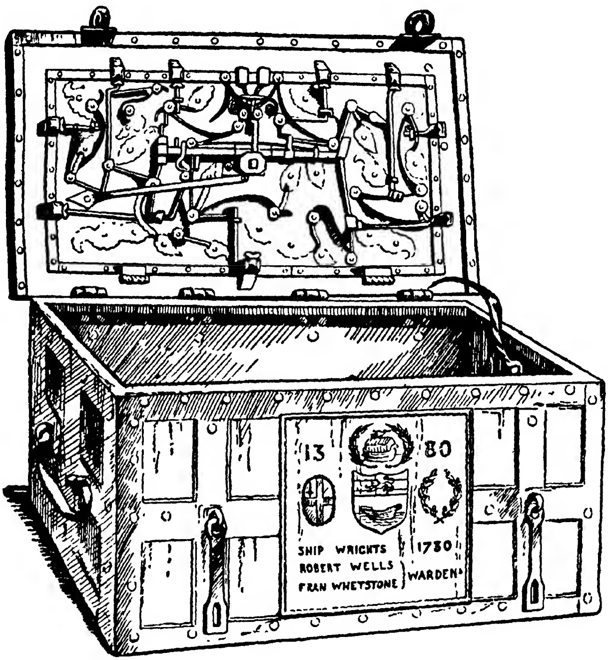


LOCK AND KEY OF TO-DAY MADE BY LIPS LTD.

moving pins into holes in the bar, as shown. To open the door, a large wooden lever or key with pegs upon it corresponding with the holes in the bar was inserted into a cavity in the beam, and the upper moving pins were pressed up so that the bar was free to move. The key was introduced into the cavity from the outside of the door through an opening large enough to admit it.

We find various references to locks and keys in the Old Testament, and a similar key to that in our illustration is carved in relief upon the façade of the Temple of Karnak, in Egypt; they were well known to the Romans, and during the Middle Ages there were craftsmen in plenty who made massive iron locks, some beautifully ornamented. Few museums are without specimens of

the medieval chest, furnished with its enormous lock and substantial metal clamps and hoops. Even these, however, could not defy the expert burglar, and it was not until the end of the 18th century that locks were invented that could do so.



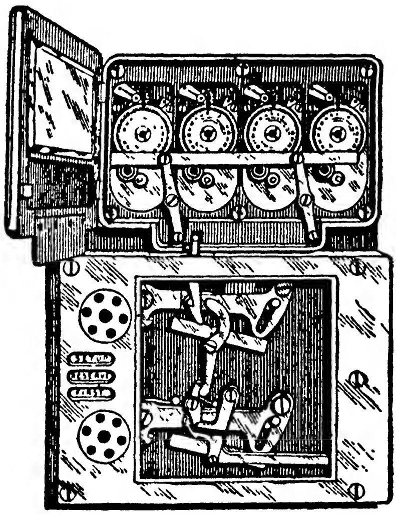
HOW OUR FOREFATHERS SECURED THEIR TREASURE
A muniment chest of the 18th century. From the original in the Guildhall Museum.

A man named Barron was the first to invent a lock of the modern type. This he patented in the year 1778—that is, just ten years before Joseph Bramah began to work upon his new lock. Bramah's lock was the first real burglar-defying lock, the first which it was impossible to pick with a false key.

It was a long and slow process to make perfect the

delicate mechanism for these new locks, and especially to make the new tools necessary for the work. Henry Maudslay, Joseph Bramah's foreman, helped him greatly, and at last, in 1784, their efforts were successful, and Bramah patented the lock.

The nature of this success will be understood when I tell you that there was a notice in Bramah's shop window offering £200 reward to any person who could pick his lock, yet it remained unpicked for not less than sixty-seven years. Many tried, but no one succeeded, until in 1851 an American lock-maker, after spending sixteen days upon the endeavour, at last did manage to pick it. But since no burglar could afford to spend sixteen hours, let alone sixteen days, on a lock, it may be fairly admitted that the lock was indeed thief-proof.



MODERN YALE BANK-LOCK, WITH TIME LOCK, BURGLAR-PROOF

Bramah's name is best remembered for his lock, but any engineer will tell you that another of his inventions was far more important. This was the hydraulic press which Robert Stephenson afterward used for hoisting the gigantic tubes of the Britannia Bridge into position.

The hydraulic press depends upon the well-known principle that water is almost incompressible. In this invention again Bramah was greatly helped by Maudslay, who devised a self-tightening collar for the piston of the machine. From his work on the hydraulic press or ram Bramah went on to invent pumps of a new sort. One which he patented in 1797 is the well-known beer

pump by which beer or other liquor can be raised from casks in a cellar to the counter over which it is sold. His rotary-motion pump was adapted to the fire-engine and soon proved its value in fire-fighting.

Bramah next invented a wood-planing machine. One of these was used in Woolwich Arsenal for more than eighty years. He followed this with a machine for planing metals by means of revolving cutters. He was the greatest tool-maker of his age, and very many modern tools are still made on the lines or methods laid down by him.

Bramah was like Murdoch in that he never stopped inventing. In the year 1806, when the inventor was fifty-four years of age, the Bank of England applied to him to make them a machine for printing the numbers and dates on bank notes. If you look at modern paper money, such as a Treasury note, you will see that each note is numbered. Within one month Bramah had invented a machine which, by its action as it worked, changed the figures and printed them in proper numerical succession. Machines of this type, with, of course, certain improvements, are still used for similar work. Bramah's new invention was so successful that it saved the labour of one hundred clerks.

We next hear of this busy inventor engaged on a pen-making machine. In those days the steel pen was unknown, and only quills were used. Bramah's quill-cutting machine remained in use for some years until in the year 1819 James Perry began making steel pens in Birmingham. I might mention, however, that brass pens had been made by Harrison of Birmingham as early as 1780, but had never come into general use. It was not until 1839 that steel pens came into general use. Ten years later two thousand hands were busy on steel-pen making in Birmingham alone, and in 1836 the gold pen, now so popular, was first made in America.

To go back to Bramah, before he died he took out more

than twenty different patents. One was for making paper by machinery, another for an improved method of making carriage wheels, a third for a preparation for making timber rot-proof. He built a wonderful hydrostatic press capable of tearing up big trees by the roots, which did actually tear up three hundred trees at Holt Forest in Hampshire. While superintending this work Bramah caught a cold, which ended in pneumonia, and he died at the age of sixty-nine in December 1814. Joseph Bramah was not only a brilliant inventor but a very good companion. He was always cheerful, full of jokes and laughter. He was very kind to his men, and would never discharge one if he could help it. He trained his assistants well, and from his shops came the famous Henry Maudslay, as well as Joseph Clement and other brilliant mechanics and inventors.

Henry Maudslay, who did so much to help Bramah with his hydraulic inventions, is chiefly remembered as the inventor of the slide-rests for lathes. Even in the 18th century, when few rich people did manual work of any kind, turning was a favourite occupation, even of royalty. George III was a first-rate hand with a lathe, knew all the mechanism, and as an old mechanic of the day said, could have made his forty or fifty shillings a week as a hardwood- and ivory-turner. Lord John Hay, Lord Gray, and others were also the owners of lathes, on which they produced all sorts of pretty bits of work.

At that time the lathe-worker had to depend entirely upon his hand and eye, and it was by no means uncommon for a man to spoil many pieces of good material by unskilful work. Especially in turning metal a great degree of strength is required to hold the tool firmly on the rest and keep up a steady pressure. If the slightest mistake is made, the chisel will cut too deep and the worker must go over the whole surface again to reduce all to the level of the cut. The chances are, in such a

case, that in the end the article is cut down too much and is thus spoiled.

Maudslay resolved to remedy this, and succeeded in inventing the slide-rest, which holds the tool securely and by a mere movement of a screw handle moves it along the face of the work as required. This may not at first sight appear to be a very great invention, but it soon made the most wonderful difference in the cost of machinery, for pistons, shafts, and other similar objects could be cut and smoothed with a quickness, accuracy, and therefore cheapness never before dreamed of.

Mention of Maudslay's invention serves to introduce one of the greatest of the inventors of the early 19th century, Marc Isambard Brunel, perhaps the most brilliant engineer of his or any other age.

It is, however, of Brunel as an inventor, rather than as an engineer, that I am going to tell you in this chapter. Brunel was a Frenchman, son of a small farmer in Normandy, who intended that his son should be a priest. But Marc cared only for machinery, and spent most of his time in the village carpenter's shop, although again and again he was scolded, even beaten. It is told of him that once, when quite a boy, he saw a new tool in a shop window, and having no money he pawned his hat to buy it. At last his father gave up the idea of putting Marc into the Church, and entered him for the Navy. Then the French Revolution broke out, and young Brunel, who was a strong Royalist, slipped away to Rouen, where he got a passage on a ship going to America.

There he obtained work as a land surveyor in the wilds on Lake Ontario, and made a little money; he then went to New York and turned architect. He designed a theatre; and next took work in a cannon foundry, where he gave his employers some new ideas for casting and boring big guns. Wages to-day are higher in the United States than in any other country, but a hundred years

ago they were so poor that Brunel became disgusted and resolved to go to England.

He landed at Falmouth in March 1800, and there met again Miss Kingdom, an English girl whom he had known in the old days in France. The two were married and were very happy together.

If in America Brunel had been Jack-of-all-trades he now showed that he had mastered more than one. A perfect stream of inventions poured from his fertile brain and clever hands. He devised a machine for duplicating drawings, another for twisting cotton thread and making it into balls. A third invention was a kind of sewing machine, after perfecting which he turned his attention to a project that had long been brewing in his brain. This was a machine for the making of blocks used in the rigging of ships. Every rope used in raising or lowering a sail must run through one or more of these blocks. A full-rigged ship of war, as then built, required no fewer than fourteen hundred sheaved blocks, each consisting of a shell of wood, with the sheaves (or pulley) revolving within, and metal pins fastening all together. Each of these blocks had to be made with the greatest care and precision so as to ensure that it would not fail in an emergency. A badly made block might be the cause of a ship losing a sail, even a mast, and the consequences might be most serious.

Before Brunel's time various attempts had been made to construct machines for block-making, especially one which was the work of Sir Samuel Bentham, Inspector-General of Naval Works, but Brunel's idea was much better.

Brunel had never had the advantage of a training in mechanics, and he found it very difficult to construct the machine which he had designed. So great, indeed, were his difficulties that perhaps the machine would never have been perfected if he had not happened to meet Henry Maudslay by a pure chance. Brunel had a friend,

a Frenchman like himself, named de Bacquancourt, and this gentleman was fond of lathe work. One day when de Bacquancourt was passing Maudslay's little shop in Wells Street he saw a piece of screw-cutting in the window, and thought it so good that he went in to ask the price. He made friends with Maudslay on the spot, and the next time he saw Brunel told him of the clever English mechanic and his wonderful work.

"The very man I am looking for!" exclaimed Brunel. "You must take me to see him."

This was arranged, and Brunel on his first visit took with him a drawing of a part of his new invention, for since he knew little of Maudslay, he thought it well not to let him know too much of the idea he was working upon. Later he called again with a further drawing, and on the following day he brought a third; each time showing only a very small part of his design.

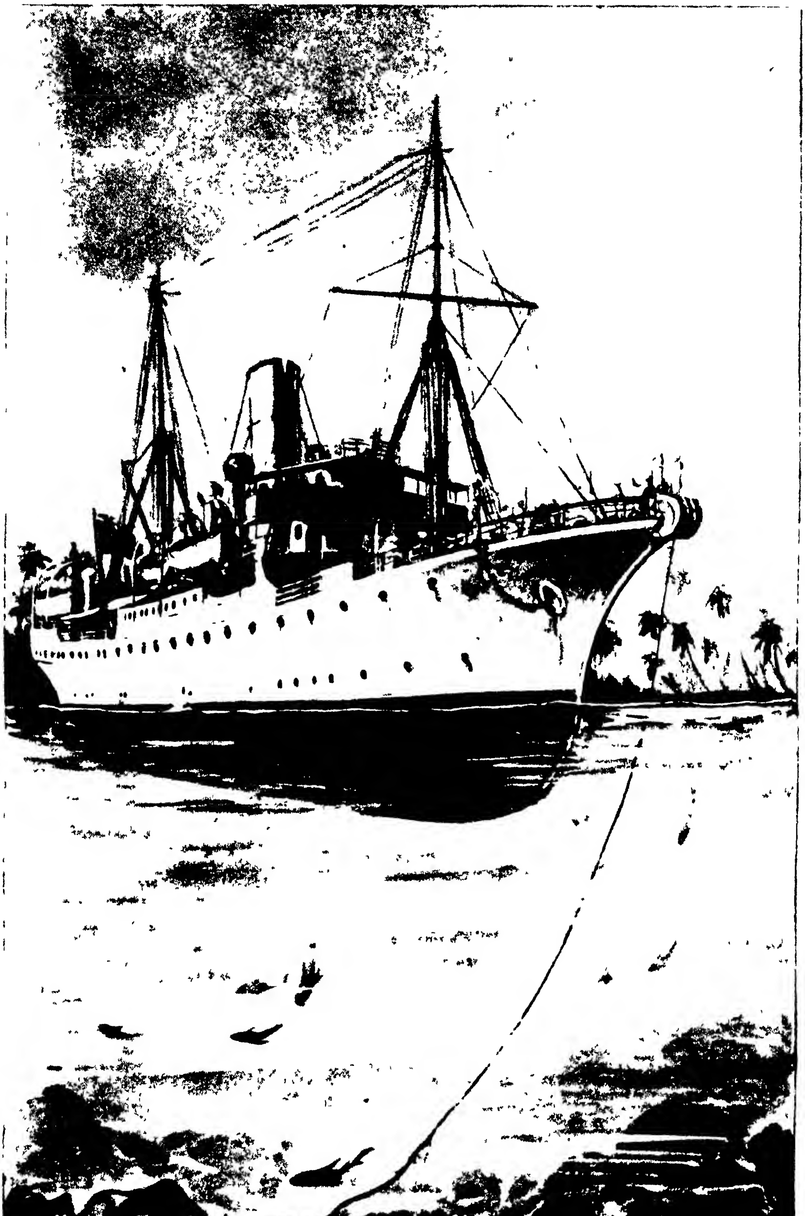
The moment Maudslay looked at this third drawing he exclaimed, "Ah, I see what you are after. You want machinery for making blocks." Brunel started, then smiled. "You are quite right," he said. "And since you have seen through my plan I will tell you all about it."

"And I will do my best to help you," replied Maudslay.

He kept his promise, and in 1801 Brunel was able to show his completed model to the Admiralty. Sir Samuel Bentham generously admitted that Brunel's invention was far superior to his own machine, and it was quickly adopted. No fewer than forty-four of the new machines were made and installed, and it was found that with these machines ten men could do the work which previously had taken the time of one hundred and ten. Both Brunel and Maudslay gained a great reputation, and the Admiralty paid Brunel a sum of £17,000. Since upon one year's work in block-making his machines saved the country £24,000, it cannot be said that he was overpaid.

Brunel was not satisfied to rest on his laurels; he got

BRUNEL AND MAUDSLAY



A CABLE SHIP AT WORK

[*Chapter X*]

work in the dockyards, and started sawmills in Battersea. These, unluckily, were burned down, and Brunel became bankrupt and was imprisoned for debt. The Government, however, granted £5000 for payment of these debts, and as soon as Brunel came out of prison he busied himself on building the first tunnel under the Thames.

Begun in 1825 this was not opened until 1843. It is interesting to note that in 1924 the eleventh of such tunnels was put in hand, and that to-day what then took eighteen years can be done in eighteen months by means of the improved appliances invented since Brunel's time. Brunel added to his inventions, and among other ingenious devices made a knitting machine, a machine for making nails, and one for making wooden boxes. He was knighted in the year 1841.

Brunel was not only a great inventor and a great engineer: he was also a most interesting character. When in society he was fearfully absent-minded, yet when in a tight place his mind worked with the speed of lightning. Once while inspecting the new Birmingham railway he was examining the permanent way when a train came thundering round the curve upon him. The spectators were horrified, expecting to see him cut to pieces. Brunel flung himself flat on his face between the metals, and lay perfectly still, and the whole train passed over him without in any way harming him.

He was most kind to his friends. One old lady whom he often visited was very fond of playing patience, but her fingers were so rheumatic that she found it hard to shuffle the cards. Brunel set his wits to work and invented a card shuffler. It was simply a little box into which the cards were put, then a handle was turned, and in a few seconds the side of the box dropped and out came the cards thoroughly shuffled and mixed.

Brunel was what is called 'double-jointed,' and had the most wonderful control over his joints and muscles.

He once had great fun with his tailor. When trying on a new coat, the tailor found that Brunel's right shoulder was so much higher than the left that the fit of the coat was hopeless. He apologized humbly and took the coat away to alter it. When he tried it again he was horrified to discover that it was after all the left shoulder that was higher than the right. " I cannot think how I came to make such a blunder," said the poor man in despair. Brunel burst out laughing, and confessed that he had just been having a little joke at the tailor's expense.

On another occasion a woman forced her way into his house, declaring that she had had an accident which had deprived her of the use of her thumb so that she could no longer earn a living with her needle. Brunel was a most charitable man, and the woman, no doubt, knew that he never turned away anyone who deserved relief.

The inventor, however, was no fool, and suspecting that there was something wrong he said he would look at the damaged thumb. The woman unwrapped the bandage and showed him the thumb, apparently deformed. He gazed at it a moment. "Ah, very curious," he said. " Almost as curious as my thumbs" ; and to the woman's confusion he showed her his own thumbs, both in the same condition as she pretended her own to be. She turned hastily, and ran out of the house, leaving Brunel laughing heartily.

CHAPTER IX

THE ELECTRIC TELEGRAPH

The Pioneers—The Morse Code—The First Telegraph Line—The English Inventors—How the Telegraph caught a Murderer—Speeding-up Telegraphy—The Chemical Telegraph and the Chronopher.

WHILE some of the properties of electricity have been known for thousands of years, such, for instance, as the fact that rubbed amber will attract small light objects, the world at large remained quite ignorant of the science of electricity until the first of American scientists grew up. I refer, of course, to the great Benjamin Franklin, who was born in 1790. He it was who first snatched lightning from the skies by means of a kite and who proved that lightning is simply one form of electric force. It was he, too, who invented the lightning rod, and it must not be forgotten that all the electrical inventions of to-day are due to the interest aroused by him in this oldest, yet to us still newest, of forces.

Like nearly all the great inventions which have benefited man, the electric telegraph is not the discovery of any one person, but rather the result of much research by many different individuals. It was the great Galileo who first had the idea of two persons at a distance communicating with one another by means of magnetism. A little later another learned Italian, a Jesuit named Strada, wrote a fanciful account of something of the same kind. He speaks of two needles magnetized by a lodestone of such virtue that the needles, balanced on separate pivots, ever afterward pointed in parallel directions. Their possessors, by mounting their needles on dials inscribed with

letters or words, would thus be able to communicate with one another at prearranged hours.

More practical was Charles Morison, a Greenock doctor, who in 1753 wrote a letter to the *Scots Magazine* in which he set down a method for sending news by electric power. This letter proves that Dr Morison knew more than a little about electricity, yet nothing came of his suggestion for more than half a century.

Somewhere about the year 1820 a certain Mr Ronalds, who lived at Hammersmith, discovered a method of telegraphy which was worked by frictional electricity. Having actually demonstrated its success over a wire a couple of hundred yards long, he invited the Admiralty to consider his discovery. The answer which he received is worthy of immortality as a monument to Red Tape. Ronalds was informed that "Telegraphs of any kind are wholly unnecessary, and no other than the one in use will be adopted." I may mention that the only telegraph in use was a clumsy arrangement of signal towers with semaphore arms that were raised or lowered like those still in use in the Navy.

A little later a French inventor, Ampère, pointed out the possibility of making an electric telegraph by surrounding the needles with wires, and later still a good many inventors busied their brains with the possibilities of electric communication. The two greatest English inventors were Wheatstone and Cooke; in America the two greatest pioneers were Morse and Vail.

The name of Morse has been preserved in the Morse Code, to-day known all over the world, and although Morse is only one of the several great men connected with the invention of the telegraph, I will begin by telling the story of his discovery.

Samuel Morse was not an inventor by profession, not even a man of science. He was an artist, and a native of Charlestown in Massachusetts, where he was born in 1791.

The Electric Telegraph

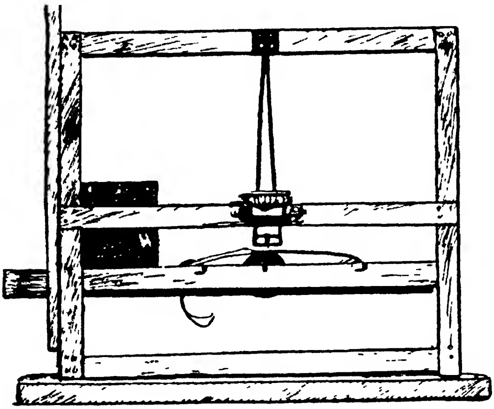
Unlike most of the inventors whom we have been discussing, young Morse had received a very good education, for his father, a clergyman, sent him to the famous Yale University. After taking his degree, he went to England, and was only twenty-two when the Adelphi Society of Arts awarded him their gold medal for a statue of the Dying Hercules. He returned to America and became first president of the National Academy of Design. An artist is generally an unpractical person outside of his own profession, but young Samuel Morse was always keenly interested in chemistry and in the new electrical discoveries which were creating a good deal of interest at the time.

He travelled frequently between London and New York, and it was on one of these voyages, in the packet ship *Sully*, that he met Dr Charles Jackson of Boston, who had been attending lectures on electricity in Paris. The *Sully* was a sailing ship, so the voyage occupied a much longer period than nowadays, and the two men saw a good deal of one another and had long talks.

Dr Jackson had an electro-magnet in his luggage, and one night at dinner he remarked to Morse that the power of a magnet is greatly increased by winding it with wire through which an electric current is passed. Another passenger asked how fast electricity travelled, and Dr Jackson answered that its speed was too great to be measured. Morse was very interested, and commented that if the electric current could be made visible at any part of the circuit he saw no reason why messages could not be sent by electricity. That night he and the doctor tramped the deck for an hour or more discussing the matter, and this conversation changed the whole course of Morse's life and led to the invention of the Morse Code and of the first practical electric telegraph.

Morse knew that an electric current would travel any distance on a wire and that the current being broken

a spark would appear. The spark might, he thought, stand for one letter, the absence of a spark for another, while the length of its absence might indicate a third. During the remainder of the voyage of six weeks Morse devoted all his spare time to devising a code; and one day, just before reaching New York, he said to the captain: " Captain, if you should in future hear of the telegraph as one of the wonders of the world, please remember that the discovery was made aboard the *Sully.*"



MORSE'S ORIGINAL CRUDE MODEL

The pen above the middle of the strip of paper made marks as this strip moved along—a short mark for a dot and a long mark for a dash. The movement was governed by the magnet above the pen.

Arrived in New York, Morse returned to his studio, but now he only painted enough to make a bare living. All his best energies were devoted to the attempt to perfect his new invention. Like most inventors he soon ran into trouble; he found that his wire offered a certain resistance to the current travelling through it so that at the end of a comparatively short distance the current became too feeble to make a record. It was Professor Gale of the University of New York who showed him that this could be overcome by a relay system. Morse and Gale together constructed a model telegraph, and found that with it they could both send and receive messages.

By this time Morse had very little money left, and his first model machine was made of such odds and ends as the wheels of a wooden clock, a band of carpet binding, and an old picture frame.

It was in 1832 that Morse had met Jackson. Five years later his invention was complete, but he had no means with which to market it. One day, early in 1837, he was showing his model to friends at the University of New York when Mr Alfred Vail, son of a wealthy family, happened to be present and was greatly interested. He had a talk with Morse, who offered him one-third share of the profits if he would provide the necessary money, and Vail accepted the offer. Vail threw himself into the work, supplied money, and helped in every way. Without his assistance it is hardly possible that Morse would ever have succeeded.

The invention was at once patented, a proper model made, and this was exhibited to various people. But months passed, and no one was convinced of the value of the discovery. At last, early in January 1838, Alfred Vail's father visited the workshop. He had little belief in the new invention, but decided to test it, and wrote on a piece of paper these words: "A patient waiter is no loser."

"Now," said he to his son, "if you can send this, and Mr Morse can read it at the other end, I shall be convinced."

Although the signals had to pass through some eight miles of wire the experiment was carried out with perfect success, and it was arranged for Morse to give an exhibition before Congress. On February 21, 1838, Morse demonstrated through ten miles of wire before the President and his Cabinet, and so greatly were they impressed that a Bill was brought before Congress to grant ten thousand dollars for the construction of a telegraph line between Baltimore and Washington. But the Bill never came to a vote, and poor Morse was bitterly disappointed.

Yet he stuck doggedly to his experiments, and even succeeded in laying the first submarine cable across New York Harbour. The wire, two miles long, was insulated

with tar and indiarubber, and it worked quite well until a ship, getting under way, caught the wire with her anchor and broke it. Congress was still Morse's chief hope, and at last, in 1842, his Bill was passed and thirty thousand dollars granted for the new land line. It was none too soon, for on the day the money was voted Morse was actually down to his last half-dollar. This small sum was all that lay between him and starvation.

You might imagine that the passing of the Bill saw the end of Morse's troubles, but this was not the case. Morse tried to lay the wire underground, only to find that this method was so costly that the money voted was totally insufficient. So he decided to use poles, and in this way he got his line finished cheaply and rapidly. On May 1, 1842, twenty-two miles were in working order, and on that day Henry Clay was nominated for President at Baltimore. Morse's first telegraphic triumph was getting the news to Washington well ahead of the train that was carrying it.

On May 24 the line was formally opened, and the historic message, "What God hath wrought," was transmitted. Congress appropriated eight thousand dollars a year for the upkeep of the new line, and charged a cent (a halfpenny) for each four letters.

The accounts for those early days are still in existence, and we find that the receipts for the first four days were a cent; for the fifth, twelve and a half cents; for the seventh, sixty cents. Then came a jump to one dollar and thirty-two cents.

Morse offered to sell his whole invention to the Government for one hundred thousand dollars (£20,000), but luckily, as it turned out for him, the offer was refused. A company was formed and other lines constructed. Money began to pour in, and all sorts of rascally attempts were made to pirate Morse's invention. But the Supreme Court of the United States handled these thieves according to their deserts, and Morse himself soon became wealthy.

Honours were showered upon him by foreign nations, and the French Government voted for him four hundred thousand francs. He lived to enjoy his riches and honours to a ripe old age, and died at last in 1872.

While Morse was busy with his telegraphic invention in America similar experiments were being carried out in England by other workers, and oddly enough the first of these was—like Morse—neither a scientist nor a mechanic. He was, in fact, an army officer, by name William Fothergill Cooke. He belonged to the Madras Army, and in 1836, when home on leave, visited Heidelberg, and there chanced to see a little toy telegraph fitted up in the lecture theatre of the University. It consisted of two electric circuits and a pair of magnetic needles which responded to the interruptions of the current.

The young officer was greatly interested; then quite by chance there fell into his hands Mrs Mary Somerville's book, *The Connexion of the Physical Sciences*, and as he read it, suddenly the idea of constructing a practical telegraph flashed into his mind. He resigned his commission, gave up everything else, and with single-hearted devotion set himself to realize his ambition.

Just as Morse found a helper in Alfred Vail so did Cooke discover one fully competent in Professor Wheatstone, a man who had deep practical knowledge of electricity and electrical apparatus. The two between them took out a patent, and in 1837 their telegraph was put into operation between the Euston Square and Camden Town stations of the London and Birmingham Railway.

On July 25, 1837, the first public trial was made, and there were present, besides many other distinguished people, the two great engineers George Stephenson and Isambard Brunel. Mr Cooke, with these, was stationed at Camden Town, while Professor Wheatstone was at Euston. The latter struck the key and sent the first

message. Almost instantly the answer came back from Camden Town. "Never," said Wheatstone, "never did I feel such a tumultuous sensation as, all alone in the still room, I heard the needles click; and as I spelled the words I felt all the magnitude of the invention now proved to be practical beyond all cavil or dispute."

As in America, it was some little time before the public at large realized the extreme importance of the new invention. In America the telegraph's best advertisement was the rapidity with which the news of a Presidential election was transmitted, but in England it was the capture of a thief.

The railway companies were the first to adopt the telegraph in England, and one of the first lines to be constructed ran along the Great Western Railway from Paddington to Reading, a distance of thirty-seven miles. Very shortly after the wire had been stretched two thieves were noticed leaving Paddington on a train for Slough. A telegram was therefore sent to the authorities there, informing them as to the carriage in which the thieves were travelling; and when the train stopped at Slough a policeman stood at the carriage door, and before allowing anyone to leave asked if any passenger had missed anything.

Almost at once a lady cried out that her purse with two sovereigns had gone. "Fiddler Dick, you are wanted," remarked the policeman to one of the thieves. The man was so thunderstruck that he gave up himself and his booty without making any attempt to escape or even excuse himself.

The news spread through Slough and Eton, and in the record of the day we may read: "Several of the suspected persons who came by the various down trains are lurking about Slough, uttering bitter invectives against the telegraph."

The story went all over England, and soon the police

everywhere began to realize what an immense power the telegraph gave them over criminals.

A little later the newly constructed telegraph line received an even more sensational advertisement. On New Year's Day, 1845, a woman named Sarah Hart was found murdered in a cottage at Salt Hill near Eton. Screams had been heard by a woman who lived in the next cottage and who, running out in alarm, had seen a man hurrying away. She said that he appeared to be dressed like a Quaker, and that she had seen a man in similar attire visiting the cottage from time to time. He had gone, she thought, in the direction of Slough Station. All this she told to a clergyman, Mr Champneys, who ran to the station, but was only just in time to see a man, answering the description given, jump into a carriage of a train that was leaving the platform.

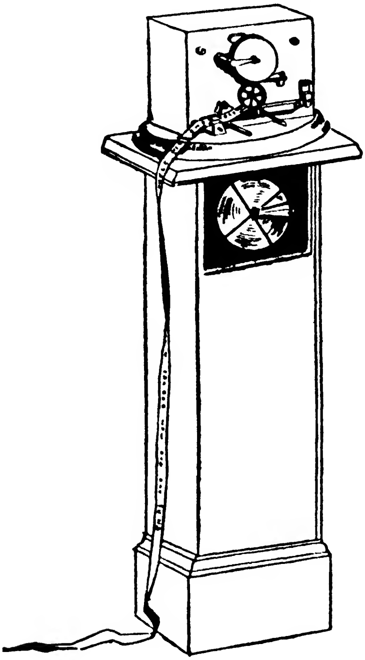
Mr Champneys found the telegraph clerk, and at once a message was sent. "A murder has been committed at Salt Hill, and the suspected murderer was seen to take a first-class ticket for London by the train which left Slough at 7.42 P.M. He is in the garb of a Quaker, with a brown great-coat on, and is in the last compartment of the second first-class carriage."

Half an hour later an answer was received. "The up-train has arrived, and a person answering in every respect the description given came out of the compartment mentioned. I pointed the man out to Sergeant Williams. The man got into a New Road omnibus and Sergeant Williams into the same."

The sergeant followed his quarry to the Mansion House, where the man got out. He then tracked him to a coffee-house in the Borough and back across the river to Cannon Street, to a lodging-house in Scots' Yard, where he arrested him. The man's name was Tawell, and, his guilt being proved beyond shadow of doubt, he was executed.

In early days telegraphy was a slow business, but

inventors have been constantly busy increasing the speed of working. The first notable invention in this direction was the Edison system of duplex telegraphy. It was while acting as a humble telegraph operator at Boston that Edison first made this invention, but it was not until the year 1872 that he perfected it. Since that date the most notable improvement has been the work of a young Australian journalist named Donald Murray. When first he became acquainted with telegraphic work the average speed of a skilled Morse operator was twenty-five words a minute, so Murray set himself to quicken this up. He brought into use four main instruments, two for transmitting despatches and two for receiving. He invented a special alphabet consisting of eighty-four characters. In the despatching office is a transmitting perforator and a modified automatic Wheatstone; at the receiving end is a receiving perforator and an automatic typewriting attachment.



A TAPE MACHINE

The despatch, instead of being punched by hand, is perforated on a tape by a machine resembling a typewriter. As soon as a message has been punched on a length of tape, the tape is cut off and inserted in the Wheatstone transmitter. The receiving perforator is actuated by electric energy and reproduces the marks made on the transmitting tape. Then, by use of a most ingenious printing machine, the message appears printed

in Roman characters. The net result of Mr Murray's invention was to increase the twenty-five-word-a-minute speed to one hundred and thirty words.

But when he offered his invention to the Australian authorities they declined it, and Murray was forced to take it to America. There he soon got a trial, and even over so long a line as that between Chicago and New York a speed of well over a hundred words a minute was obtained. In 1902 Murray visited England, and proved the great possibilities of his invention to the British Post Office authorities.

As I have said, the English railway companies were the first to adopt the telegraph, but in 1846 the Electric and International Telegraph Company was formed, and took charge of all lines. Their charges were very high, for in the fifties of the last century it cost ten to twelve shillings to send a message from London to Edinburgh. Two wires were then necessary to send the simplest message, and the wires themselves were badly constructed. The insulation was poor and the poles so badly set that in a storm they went down like ninepins.

The Electric Company introduced the Chemical Telegraph invented by Alexander Bain, an Edinburgh clockmaker, and a great genius who, unfortunately for himself, lived half a century too soon. His invention was marvellously simple. Chemically prepared paper tape was unwound from a roller driven by clockwork. A thin steel needle was made to rest upon the paper, and as this needle received the current blue marks were produced on the strip of paper. Bain's instrument, elaborated, is the base of all rapid systems of to-day; but Bain himself made little or nothing out of his great invention, and was left to die in poverty.

Another most interesting invention which was brought in by the old Electric Company was the chronopher, which may perhaps be described as the British Time

Keeper. Its function is to automatically convey to all parts of Britain Greenwich mean time at 10 A.M. and 2 P.M. Cromwell Fleetwood Varley was the inventor of this intricate and beautiful piece of mechanism, which will probably continue to be used as long as the present system of telegraphy remains.

CHAPTER X

SUBMARINE TELEGRAPHY

Its Debt to Sir William Thomson—The Laying of a Cable—Various Inventions.

YOU might fancy that, once telegraphy had been proved a success on land, the submarine cable would have been a simple development. After all, it is only a matter of sufficiently insulating the wire, then laying it on the bottom of the sea.

That is just what the electricians of Morse's time thought, but they soon found that the matter was not so simple as it seemed. The fact is that a long cable, with a metallic core and insulating sheath and salt water outside, acts like a gigantic Leyden jar or condenser. The current, flowing along the copper core, induces in the water opposing currents, and these reduce the speed of transmission. To begin with, the currents must be weak, for if they are too strong they will ruin the cable, as happened in the case of the first transatlantic cable laid in 1858. This lasted for twenty-three days only, then went 'dead.'

It was a terrible blow to Cyrus Field and the other promoters, for the expense had been enormous. Now it seemed as though the money had been utterly wasted, and that it was impossible to establish electrical communication across the breadth of the Atlantic.

But there was a man living who thought otherwise. This was William—afterward Sir William—Thomson, one of the greatest scientists of the 19th century. William Thomson was born in 1824 at Belfast in Ireland; but while still quite a small boy his father was appointed Professor

of Mathematics at Glasgow University, and it was at this University that young Thomson received his early education, and where he first became interested in electricity. Later he went to Cambridge, where he did well both in work and games. One's general idea of a scientist is a short-sighted, thin-chested person with big glasses, but young Thomson was a fine athlete and also interested in music. Science, however, was his first love, and so brilliant was he that in 1845 he was awarded a fellowship of two hundred pounds a year, which enabled him to study in Paris. Then at the very early age of twenty-two he accepted the Professorship of Natural Science at Glasgow. The University had no laboratory, but young Thomson, with tremendous energy, raised funds for equipping one, and there began the experiments in electricity which, later, made the Atlantic cable a real success.

Thomson had foreseen the difficulties attending the sending of messages through nearly two thousand miles of insulated cable, and he realized that what was required was a method quite different from that used on land lines. The current sent could be but tiny, and his idea was to make it visible. It was for this purpose that he invented his mirror galvanometer. Before Thomson's day, Oersted, the famous Danish philosopher, had made the discovery that when a current is sent along a wire in the neighbourhood of a freely suspended magnetic needle, the needle will be deflected, and its new position will be right or left according to the sort of current sent through the wire. More than this, the amount of deflection will depend upon the strength of the current.

It was by taking advantage of these discoveries that Thomson invented his mirror or reflecting galvanometer. The wire through which the current to be measured is made to pass consists of many turns of very thin insulated copper wire, forming a hollow coil, in the heart of which

a tiny needle is suspended by a gossamer thread of floss silk. The magnets carry a wee circular mirror, the whole arrangement of magnets and mirror being no longer than four or five of these printed letters which you see before you. A beam of light is thrown from a lamp on to the mirror, and reflected back from the mirror on a graduated scale. The distance to which the reflected beam is moved along the scale measures the strength of the current passing through the coiled wires, and so the resistance of any wire to any particular current can be accurately measured. Also, the mirror galvanometer affords a means of making visible to the operator currents far too feeble to work the ordinary sounder.

The amazing delicacy of Thomson's apparatus is proved by the fact that when the first Atlantic cable had been successfully laid so little current was required that the cell used for sending the messages was made from a lady's silver thimble, a bit of zinc, and a few drops of sulphuric acid. Yet this incredibly tiny current after crossing the whole Atlantic was easily visible by means of Thomson's galvanometer.

The first submarine cable was laid between England and France in the year 1850, and two years later England and Ireland were connected. It was in 1857 that the first attempt was made to lay a cable across the Atlantic, and the story, though it has often been told before, is so interesting that I will repeat it. In June 1858 the *Niagara* and the *Agamemnon,* the latter a warship lent by the British Government, sailed, each having aboard one-half of the great Atlantic cable destined to join the Old World and the New. It was at first intended that the two vessels should proceed to mid-ocean, there splice the cable and steer, one for Newfoundland, the other for Ireland. But this plan was changed, and it was decided that the *Niagara* should start from the Irish coast westward, accompanied by the other vessels of the

fleet, and, when she had finished 'paying out' the cable, that the *Agamemnon* should continue the laying.

Luck was against the expedition from the start. An appalling gale arose, and the *Agamemnon* was forced to fly before the storm for thirty-six hours. Her coal got adrift, two of her sailors were badly injured and one actually went mad with fright.

Captain Priddle, her commander, managed, however, to weather the hurricane and get his ship to the agreed rendezvous, where he met the *Niagara*. The splice was made, and the two vessels steamed away, but hardly were they out of sight of each other before the cable snapped. It was fished up, spliced, and the process of laying resumed again and again, but every time with the same ill-fortune. The fact was that during the storm the coils of cable aboard the *Agamemnon* had shifted and become kinked. In the end, having lost three hundred miles of valuable cable in mid-ocean, the expedition was forced to return home.

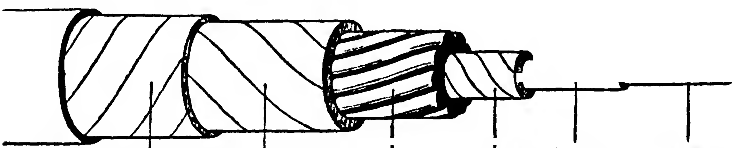
The managers of the Company were not disheartened. More cable was put aboard, and on July 17 a fresh start was made. To the amazement of everybody, on August 5 the *Niagara* safely arrived in New York, bringing news that the task was safely finished. The excitement was tremendous, and reached its climax when, on August 16, the President of the United States received the first telegraphic message from Queen Victoria.

But this new cable was poorly made, and, as I have explained, would not stand the heavy current that was being forced through it. At the end of twenty-three days it ceased to work, to the bitter disappointment of all concerned. Four hundred messages in all had been sent across it, and it is worth mentioning that one of these sent from the War Office in London to countermand the return of a certain regiment from Canada to England had saved the tax-payers of Great Britain the

sum of fifty thousand pounds. In 1865 the Atlantic cable was recovered and repaired, and in 1866 a new cable was laid. This was one thousand eight hundred and ninety-six miles in length and weighed three thousand three hundred tons.

Many inventions besides that of Thomson have gone toward making the deep-sea cable a success. One of these was the adhesive mixture named Chatterton's Compound. It is made of resin, gutta-percha, and Stockholm tar. It is not only adhesive, but also absolutely waterproof and, into the bargain, a good insulator.

There is perhaps no other article made by man over



MAKE-UP OF A SUBMARINE CABLE

the manufacture of which more care is taken than a submarine cable. The slightest fault, you will realize, destroys the value of the whole cable. Never was there a better example of a chain being no stronger than its weakest link. All the materials are carefully watched, especially the iron wires used for sheathing, which are tested for stretching, twisting, and breaking strains. As each mile of cable is made and coiled away, its properties are separately chronicled. And even after it is completed the whole cable is electrically tested every day. When finished in the manufactory the cable is coiled in great tanks filled with salt water until it is taken away for laying.

The laying is always a difficult and intricate business, and could not be done but for the skill of numerous inventors. Before the days of steamships it would have been impossible to lay a cable, for in order to do so it is

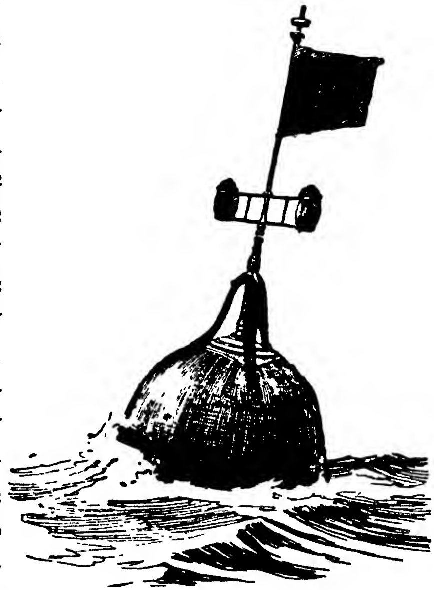
essential that the ship should be independent of wind and weather. The modern cable ship is fitted with screws at either end, so that she can reverse her motion without the need for turning round. She is provided with huge iron tanks for containing the cable and with very special machinery for paying it out and hauling it in. Particularly ingenious is her machinery for taking deep-sea soundings. It was Brooke, an officer of the United States Navy, who invented the modern method of sounding by using a detachable weight, the sinker being left at the bottom, and only a small tube containing a sample of the bottom being hauled up with the line. Later, sounding by means of a wire rope for telegraphic purposes was carried out by Sir William Thomson. The diameter of wire being so much less than that of rope there is less friction, and wire runs out and can be hauled in more rapidly than rope.

Another very ingenious invention for sounding purposes is Siemen's Bathometer. The bathometer has a dial like that of a barometer. It stands in the captain's cabin, and indicates by means of a needle the depth of the sea over which the ship is passing. Its action depends on the attraction of the earth upon a column of mercury.

Suppose a cable ship, all loaded up, properly equipped and manned and ready to begin paying out the cable. The cable cannot, of course, be allowed to run out by its own weight, but must be checked by certain mechanism so that it may pay out evenly. On the other hand, it must not be checked too hard, for if this should occur, it would be very easy to strain or break the cable. It is necessary, therefore, to know exactly what tension or pull there is upon the cable at any time, and for this purpose two inventions are needed.

One is the friction brake first invented by Appold; the other is the dynamometer. The latter consists of three pulleys, two fixed and one a riding pulley. The cable

passes over the fixed pulleys and under the riding pulley. The weight of the latter pulls it into a V-shape, and the depth of the V becomes less as the tension on the cable increases. So the speed of the ship can be adjusted to give the right amount of slack. The revolution of the drum of the brake, the strain on the cable, and the number of turns of the ship's screw are observed the whole time, night as well as day. Down in the electrical testing room the same careful watch is kept, the cable being charged so as to see that it remains properly insulated. This is where the galvanometer already described proves so useful.



A CABLE BUOY

If any 'fault' is reported, the ship is instantly stopped, and tests are applied to find where the fault has occurred. So perfect is the modern apparatus that a fault is usually perceived before the faulty length has sunk into the depths. Then the cable is cut, the faulty part removed, a new splice is made, and the laying goes on as before. If it should happen that the faulty part has been laid upon the bottom the 'picking up' gear is used, and the cable hauled slowly in by means of a steam winch.

At best, cable laying is a ticklish operation, and in bad weather desperately difficult and even dangerous. In a really bad storm it may become necessary to cut the cable, buoy the end, and leave it until the weather moderates.

CHAPTER XI

ROADS AND BRIDGES

The Romans—Roads in the Middle Ages—The Great Work of Telford—His Giant Suspension Bridge—Wood Paving and Asphalt.

YOU may perhaps think that the making of a road is not an invention, and therefore should not be described in a book about inventions. There, however, I should differ from you, for good roads are the very essence and beginning of any civilization, and no country can become great or prosperous without such ways of communication.

Besides, a man like Telford, to whom we owe the modern road, was a true inventor, and many patents have been taken out for road-making materials and methods, especially for pavements.

The Romans were, of course, the great road-makers of old, and England's first roads were made by the Romans. These were: Watling Street, which ran from Kent to Chester and York, branching thence to Carlisle and Newcastle; the Fosse Way, from Bath to Lincoln; and Ickneild Street, which led from Norwich to Dunstable. Roman roads were narrow—from eight to fifteen feet in width—and ran straight up hill and down dale; they were bottomed with stone cemented with lime, and paved solidly with flat stones. Their cost must have been enormous, and they were so wonderfully made that the remains of some are still visible after nearly two thousand years.

After the Romans left England their roads decayed or became buried, and in the Middle Ages England was practically roadless. Little was done until 1346, when

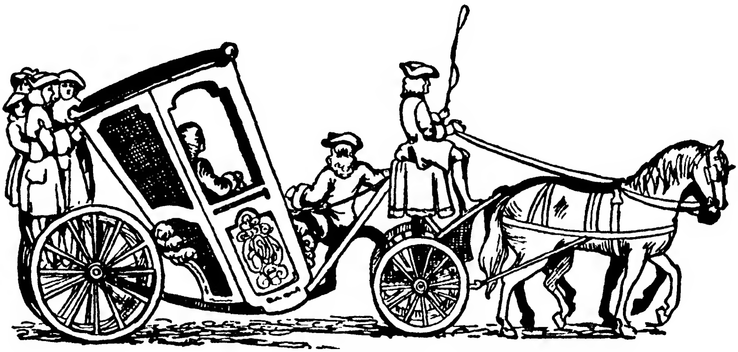
Edward III levied a tax for repairing roads and streets in and round London. Yet nothing came of this, and it was not until 1555 that an Act of the English Parliament ordered each parish to elect two surveyors to keep the roads in order. How much or little good this did is proved by a treatise published in 1610, the author of which had a plan for building roads with wooden frames filled with stones, cinders, or gravel. He says, " There are

A TOLL GATE

very little or no waies, to the dayly, continuall, and great grief and heart-breaking of man and beast, and sometimes to the great and imminent danger of their lives, and often spoile and loss of goods."

About 1620 it was suggested that each parish should set up toll-bars to which the out-of-works should carry stones or gravel. These should be loaded into baskets, and each vehicle, on reaching a toll gate, should pay a penny for a forty-pound basket of stones and empty it into the next hole in the road. Defoe, the famous author of *Robinson Crusoe,* had the idea of employing all prisoners on the roads, with overseers to make them work.

Yet well on into the 18th century the roads remained in the most disgraceful state. In 1736 the roads round London were so bad that in wet weather a carriage could not be driven from St James's Palace to Kensington in less than two hours. Even the King's own carriage was more than once stuck in the mud. Such roads as existed were made of gravel, which in some places was piled up eight feet above the surrounding fields. They had no bottom; they were mud in winter, dust in summer, and



A STATE COACH, 18TH CENTURY

whenever the floods were out the whole roadway was washed away and disappeared. Even in London and other great towns the streets were deep in filth, and open drains, smelling most horribly, ran down the side or sometimes in the centre of the roadway.

In 1788 the first mail-coach reached Glasgow, but the road was so bad and the bridges in so dangerous a state that the service had to be given up until repairs could be made. These repairs could not have been very successful, for in newspapers of 1814 there is an account of an accident when a coach and four horses fell through a bridge. The driver and one passenger were killed and "several other persons dreadfully maimed." Would you believe it? The bridge was left in this condition for months, the overseers stating they had no money to

repair it. It was not until the year 1816 that Parliament passed an Act to spend £50,000 on this road, and the work was placed in the hands of the celebrated Telford.

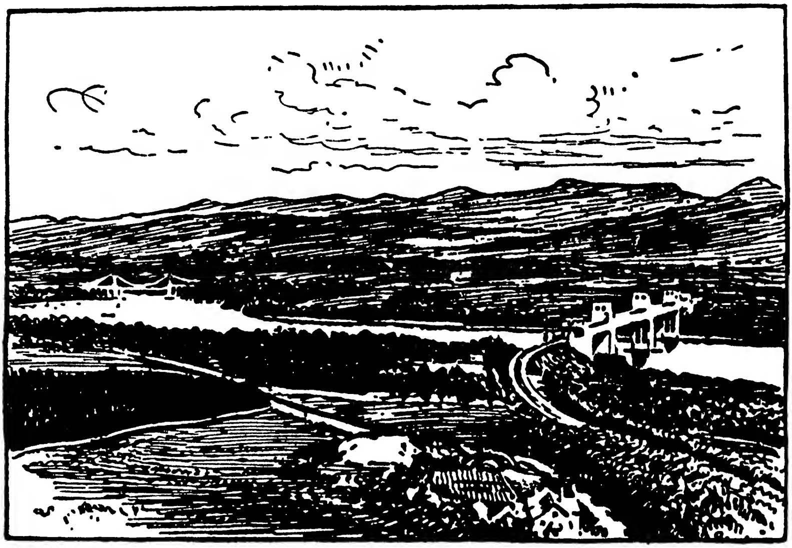
Thomas Telford, like so many of the great men of his time, had risen from the ranks. He was a stonemason, the son of an Eskdale shepherd, and had educated himself. In 1782 he came to London and helped to build Somerset House; two years later he was working on Portsmouth Dockyard. He never wasted his time or chances, and by the time he was thirty was Surveyor of Public Works for Shropshire. He was then put in charge of the construction of the Caledonian Canal, which was cut through Scotland and joins the North Sea to the Atlantic, and after much other canal work was asked by the Government to take charge of Scottish roads.

He built more than a thousand miles of roads in Scotland and some twelve hundred bridges, besides harbour works and public buildings of all sorts. He was jokingly called 'the Colossus of Roads,' and no man better deserved the title.

Telford was the first man since Roman times to realize that a road, in order to last, must have a good foundation and proper drainage. He planned his roads so that there should be no slope rising at a steeper angle than one foot in thirty. He made the foundation of his road of two layers of stone, the bottom course being seven inches deep. The stones of good size were all set by hand, with the broad ends downward, and no stone was more than three inches across at the top. The spaces between were filled with smaller stones, packed by hand so as to make a level surface. The top course was of stones none too large to pass through a two-and-a-half-inch ring, and these were so arranged that the middle or crown of the road was four inches above the sides. A binding of gravel, an inch in thickness, covered all, and a drain ran beneath the road to the outside ditches at every hundred

yards. The result was a roadway which for horse traffic has never been improved upon, and it is only since motor vehicles came into use that a new system of road-making has become necessary.

After his work for Scotland, Telford went to Wales, and did wonders for the roads in that mountainous country. He was the boldest of engineers, and would



THE MENAI STRAIT, WITH TELFORD'S BRIDGE IN THE DISTANCE

blast away a whole mountain side to save a mile or two in distance. After this came the greatest of Telford's life-work, the building of the huge suspension bridge across the Menai Strait.

This was begun in the year 1820, and it took four years to erect the huge piers, three on the Welsh and four on the Anglesea side. Telford had nothing to guide him in setting up the monstrous iron chains which were to carry the bridge, and all the tests and calculations had to be made by himself. The bars forming the main chains were three and a quarter inches square, and were tested

to bear a strain of nearly ninety tons before breaking. The weight of each chain between the piers from which it was to be suspended was twenty-three and a half tons, and Telford calculated that a strain of about forty tons would be needed to raise it to its place. Bets were freely made that he would never succeed in raising these chains, but Telford went quietly on with his preparations, and on April 26, 1825, all was ready.

Just before high tide an enormous raft, no less than four hundred and fifty feet in length, with the chain stretched upon it, moved out from the shore, and, swinging round, was moored against the two main piers. One end of the great chain was then fastened to another chain which hung down the face of the pier on the Welsh side, and the other attached to ropes which ran through gigantic blocks over the opposite pier, and so to capstans on the Anglesea side. No fewer than one hundred and fifty stout workmen manned the bars of the capstans. A band struck up, and, keeping time to the music, the men began to step round at a lively pace.

It was just like getting up a huge anchor. The ropes came coiling in, the chain began to lift, and when after a little while it rose quietly off the raft the huge crowd that had come to watch broke into a roar of cheering. Telford's arrangements were so perfect that there was no hitch, and within about an hour and a half the whole chain was stretched in its proper position high above the water and made fast. Telford had kept perfectly calm throughout; but when it was all over, and his friends ran to congratulate him, they found him on his knees murmuring a prayer of gratitude that he had succeeded in the great work. He afterward told one of them that he had been so desperately afraid lest some of his calculations were wrong that for many nights he had hardly slept. Fifteen more chains had to be raised, but all was done without trouble; and in January 1826 the great bridge

was opened for traffic, and the London and Holyhead mail-coach horses trotted gaily across.

Telford was now seventy years of age, but so far from retiring he went on to construct the great St Catherine's Dock in London, which has a huge tide-lock with three pairs of gates. Next, he built the splendid stone bridge over the Severn at Gloucester, with its great arch one hundred and fifty feet in width. He built Dean Bridge at Edinburgh, and his last great work was the wonderful bridge across the Clyde at Broomielaw. I am not quite correct in saying that he built it, for he died before it was finished, but it was completed exactly according to his designs.

Many stories are told of the great Telford. During his frequent visits to London he stayed at the Ship Hotel at Charing Cross, where rooms were kept always ready for him. After many years he decided to take a house of his own, and one day mentioned to the landlord that he had done so and would be moving into it in a week or two. "What, leave my house!" gasped the landlord. "Why, sir, I have just paid seven hundred and fifty pounds for you."

Telford stared in amazement, while the landlord explained that he, Mr Telford, had been looked upon as a fixture in the hotel, and so valuable that each incoming landlord had paid for him as part of the goodwill of the house.

Foreign Governments often consulted Telford. The road from Warsaw to a place called Briese was built from his plans, and so was the fine suspension bridge between Buda and Pest. It is only during the present century that the Panama Canal has been cut, and then the project was backed by the national resources of the United States. The French engineer de Lesseps had tried and failed to make the canal, and most people are under the impression that he was the first to have the

idea of so gigantic a piece of engineering. But the truth is that Mr Telford saw the possibilities of connecting the Atlantic with the Pacific more than a century ago, and actually made plans for the work. Thomas Telford was buried in Westminster Abbey in 1834, and next to his remains lie those of Robert Stephenson, who had always wished that his body should be laid next to that of the man he so greatly admired.

Wood pavement, which is now so largely used in the streets of towns, was the invention of a Mr Finlayson, who lived at the same time as Telford. He used it first in 1825, but, perhaps because he did not have a good founda-

NEW BRIDGE AT SYDNEY

tion beneath it, the new paving was not popular. Even asphalt paving is a much older invention than is usually supposed, for ninety years ago a patent was taken out for paving streets with asphalt. Ninety-three parts of asphalt were mixed with seven parts of bitumen or pitch, and were melted together and spread on a concrete foundation.

So long ago as 1838 an asphalt pavement one hundred and fifty feet long and ten wide was laid down at Whitehall in London. It is rather amusing, in looking up records of that time, to find that the principal objection made to using asphalt as pavement was "the difficulty in raising and re-laying it, a process so constantly required to reach the innumerable gas and water pipes beneath." Now, more than eighty years later, asphalt has come to stay, but the street-breakers are still at work tearing it up in order to get at the pipes which, to-day, are even more numerous than they were in the early 19th century.

CHAPTER XII

THE SEWING MACHINE

The Tragedy of Thimonier—The Struggles of Elias Howe—Isaac Singer makes a Great Fortune.

THE Red Indians were so much annoyed when the first railway was driven through their Western hunting-grounds that, as the first train came along, they attempted to stop it by holding a rope across the rails. The train went on, and the unfortunate Indians were dragged under its wheels and killed.

The path of the inventor is beset with such difficulties. He designs a machine by which one man can do the work of ten, twenty, or even a hundred. At once he meets the most strenuous opposition from workers whom his machine threatens to displace, people who cannot see that such an invention is bound, in the long run, to make life easier for all. The model may be destroyed, the inventor may be injured, even killed, yet not even the fiercest opposition has been able to retard for long the arrival of any really useful invention.

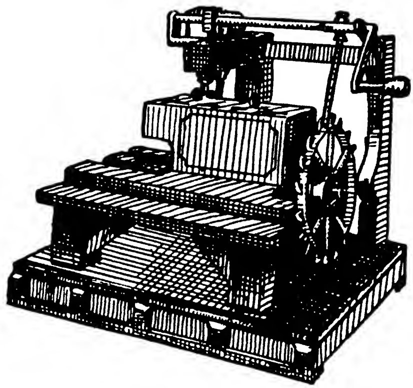
Perhaps there never was an invention which saved more human toil than did the sewing machine, for less than a hundred years ago every garment was slowly stitched together by hand. The wages paid to seamstresses were cruelly low, and thousands of sewing women and men lived in a state little, if any, better than slavery. To these people the sewing machine was actually the means of deliverance from misery; yet seldom, if ever, has any invention been met by more bitter opposition.

It seems curious that it was not until the middle of the 18th century that a machine for sewing was devised.

The Sewing Machine

The first attempt to produce such a machine was made by a German tailor named Weisenthal in 1755, who used a double-pointed needle, eyed in the middle. Then half a century passed before John Duncan, a Glasgow machinist, went a step farther and made an embroidering machine, the drawings of which show that he had some idea of the loop-stitch.

But neither of these was a real sewing machine. The first was that invented by Thomas Saint, a London cabinet-maker, who in 1790 patented a machine for sewing leather. This was actually on the chain-stitch principle, but the specifications were poorly made out, and Saint does not appear to have manufactured any of his machines. The description was buried, forgotten, in the Patent Office until nearly eighty years later some one interested in sewing machines discovered it. Saint's machine had the overhanging arm of the modern machine, the perpendicular action, the eye-pointed needle, and a feed equal to that of most modern machines. Never was there a more singular case of really great invention coming to nothing simply because its inventor had not the skill or business ability to put it forward.

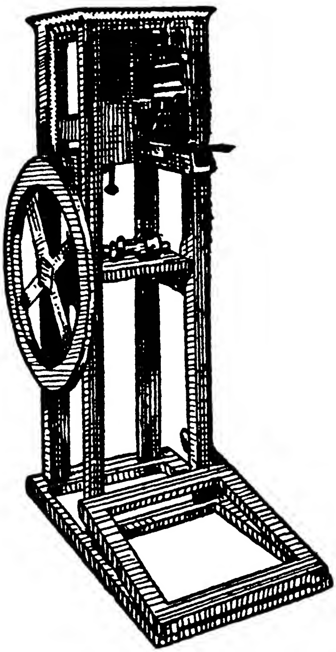


SAINT'S MACHINE

Saint's machine died, you may say, before it was born, and forty years passed before we hear of any other similar invention. In 1830 a Frenchman named Thimonier devised a workable sewing machine specially intended for stitching gloves, and with this he began to work in Paris. Finding it answer, he went on to adapt his machine for making army clothing. The news spread among the

workmen that one machine could do the work of ten men or women, and a mob of poor, ignorant wretches broke into Thimonier's workshop and smashed his machine; he himself had to run for his life.

Thimonier stuck to his guns, however, and four years later returned to Paris with a new and greatly improved machine. Again the mob gathered, and again the unfortunate man was forced to fly. He then made a tour through French towns, showing his machine wherever he went, and, by making a small charge, gaining some sort of living. At last he met a man with money, who offered to become his partner, and the two set up a factory for the manufacture of the machines. But in 1848 revolution broke out in France, the factory came to grief, and the unlucky inventor was left to starve. He died in 1859, it is said, of a broken heart.



THIMONIER'S MACHINE

Meantime American inventors were busy. Walter Hunt, a citizen of New York, patented a machine on the lock-stitch principle in 1853, but very little is known of the man or his invention. To Elias Howe must be given the credit for the invention of the first practical sewing machine, and for making a success of it.

Elias Howe was born in 1819, the son of a miller in the small town of Spencer in Massachusetts. The first spinning factories were then being built in New England, and poor little Elias, at the early age of six, was sent to

work in one of these. His only schooling was for a few weeks each summer. Elias had his ambition, and when sixteen went away to the big town of Lowell and got work there in a cotton factory. In 1837 this closed down, and Elias was glad to get a job in a machine shop. He was still very young when he married and went to Boston, where he worked as a mechanic.

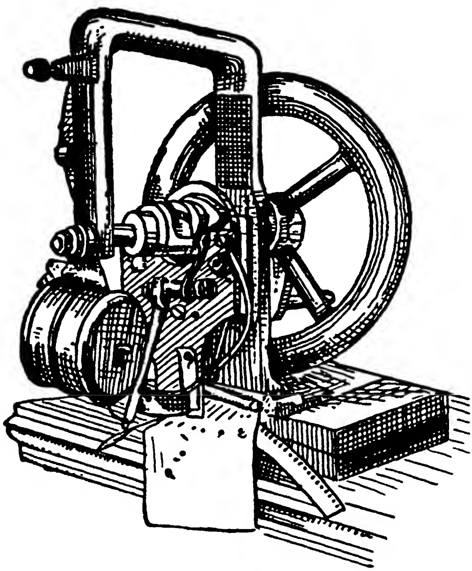
The young man was a born inventor, and showed it by constantly suggesting small improvements in the machine shop where he worked. The notion of a sewing machine first came into his mind in 1841, soon after he came to Boston, and he became so interested that he gave up every evening to experiments. His first idea was to make a machine that would imitate the hand; that is, thrust a needle through cloth and push it back again. So his first needle was sharp at both ends and had an eye in the middle. For a whole year he worked on these lines, but was driven at last to abandon this method for one which would give a different form of stitch.

One day there flashed into his brain the idea of passing the thread through the cloth and securing it on the other side by another thread. Here was the germ of the modern lock-stitch. Howe went on to make a shuttle and a curved needle, and at last, in the autumn of 1844, he put together his first machine, and to his great delight found that it would work. This machine, besides its special needle and shuttle, had a feed mechanism and holding surfaces to keep the cloth in position.

Feeling certain that success was within his grasp, Howe gave up his work in the machine shop and devoted all his time to an attempt to make his new machine known. First he made for himself a suit of clothes with the machine, and next he challenged five of the most expert sewers in a Boston clothing factory to a sewing match. Each was to sew one strip of cloth, but Howe himself was to sew five strips before any of the others had

completed one. Howe's triumph was complete, for his five strips were finished before any one of the hand-workers had completed even half of his task.

The young inventor was delighted. He expected congratulations, but instead met with black looks and threats. "Trying to take the bread out of poor men's mouths!" was muttered on every side, and soon to his horror the inventor heard of a plot to smash his machine and drive him out of the town. He had spent all his money, he had given up his work, and had made himself so unpopular that no one would employ him, so in despair he followed Thimonier's example, and went to other towns, exhibiting his machine for a small admission fee. Meanwhile he left his wife with his father in Cambridge, Massachusetts.



HOWE'S MACHINE

Misfortune piled upon misfortune; his father's house was burned down, and black ruin stared the Howes in the face. Yet Elias did not lose heart, and took odd jobs so as to provide food and shelter for his family.

At last the tide turned. The young inventor fell in with a man named Walter Fisher, who was an old schoolfellow and had a business as coal-dealer. Fisher saw the possibilities of the machine, and put up five hundred dollars in return for a half-interest in the patent, if one could be obtained. In December 1844 Howe moved to the house of his friend, and set to work to construct a

perfect model, which he finished in the spring of 1845. But though many people saw the machine and all praised it, no one would buy it. Howe was forced to take work on a railway, but his health broke down and once more matters looked black indeed. But Elias Howe was not the man to give up, and, scraping together a little money, he sent his brother Amasa to England with the model, to see if he could find some one there who would take it up. Amasa succeeded in making terms with William Thomas, a staymaker who had a shop in Cheapside. This man offered two hundred and fifty pounds for the use of the machine, and sent word to Elias that he would give him work at three pounds a week if he came over. Elias thereupon came to London, bringing his wife and their children, and set to work for the staymaker. Thomas, however, proved a hard master, and, at the end of eight months, Elias threw up his position. He used the last of his money to send his wife and children back to America, then set doggedly to work to find some one to finance his invention. No one would look at it, however, and in the end the inventor was forced to pawn his model so as to raise funds to return home. He had heard his wife was very ill, and he longed to see her. He reached Cambridge to find her dying, and a few days later she was buried.

Even now Fate had not done its worst, for the inventor found that various unscrupulous people had pirated his machine, and were using and selling their models. Yet Howe would not despair, and somehow or other he raised money to redeem the model which he had left in London and to start actions against those who were infringing his patent. As was the case with Morse, Howe found that the United States Supreme Court had little toleration for patent-thieves, and he won a hard-fought victory. Then came the discovery that the thieves who had tried to steal his machine were liable for the payment of

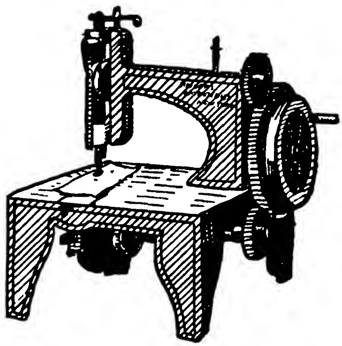
royalties. Money began to flow in, and, into the bargain, the lawsuits had given the sewing machine a great advertisement. In a very short time Howe was comfortably off, and before his patent expired in 1867 he and his partner had received two million dollars (£400,000) in royalties alone.

Howe's machine was shown at the Paris Exhibition in 1867, and was awarded a gold medal, while Howe himself received that much coveted French decoration, the Legion of Honour. His income at this time was two hundred thousand dollars a year. But the poor man's health had been broken by his long struggles for success, and in October 1867 he died in his house at Brooklyn.

Howe's machine, wonderful as it was, looks very rough and crude compared with the light and dainty modern machine. In order to trace the development of this we must go back to 1849, when Allen Wilson, a young inventor, who knew nothing of Howe's invention, created a sewing machine on very similar lines to Howe's, but in some respects superior. Like Howe's it had a curved needle. One of these machines was sent one day to a New York factory for repair, and fell into the hands of a young mechanic named Isaac Singer, who, after looking it over, came to the conclusion that he could make a better one. Singer's principal idea was that a straight needle would be an improvement upon the curved one.

In 1850 he set to work, but a hard struggle awaited him. He had to contend with popular prejudice due to the previous failures of others to produce a successful working machine. Starting with a capital of forty dollars —and that borrowed—discouragements and disappointments met him at every turn, for a man who pretended to have a working sewing machine was considered an impostor. Thousands had bought other machines which they were obliged to throw away as useless. Whoever then attempted to introduce a new sewing machine had

to face the consequences of previous failures, and this Mr Singer quickly learned to his sorrow. Everywhere he found people unwilling to believe that a successful sewing machine had actually been built, and repeatedly he was shown to the door the moment he had stated his business. Still the undaunted mechanic struggled on in poverty, bearing up under reverses and disappointments—actually, at one time, giving practical sewing demonstrations with his own machine on doorsteps to prove his point. Slowly and by degrees he gained the confidence of the public. His machine received a trial, and every time it made good. And so this humble millwright, who in 1850 was working for a dollar and a half a day, died twenty-five years later worth fifteen million dollars, leaving a name—the name of Singer, which is a household word to-day.



THE FIRST SINGER MACHINE

Another inventor to whom users of sewing machines owe a great debt is the late James G. Gibbs, who made the first successful chain-stitch machine. Howe, Wilson, Singer, and Gibbs were the pioneers of the sewing machine, but many others have since helped to make it the perfect piece of mechanism it is to-day, more than one thousand different patents having been taken out for various improvements.

To-day sewing of every kind is done by machinery, from delicate embroidery to the stitching of boot soles, and the sewing machine is found all over the world, from the shores of the Arctic Ocean to the leaf-thatched hut of the African negro.

CHAPTER XIII

DIVING-SUITS AND DIVING-BELLS

Diving for Pearls—The Inventions of Siebe and Fleuss—Pino's Hydroscope and Elevator—What Divers do.

ONE hears a good deal about the high cost of clothing to-day, yet the ordinary citizen gets off cheaply when compared with the diver. His is the heaviest suit that any man ever wears; the leaden-soled shoes alone weigh 40 lb., while two 16-lb. weights are hung round the diver's neck, and when arrayed ready for descent he is wearing in all something like 160 lb. weight of equipment.

But we are getting on too rapidly, so for the moment let us turn to the beginnings of under-sea work. Diving is one of the world's oldest industries, for pearls have been treasured as far back as history extends. But for thousands of years the treasures of the deep were got without the aid of diving-bells or diving-suits, and even to-day men still dive to depths as great as ten fathoms without artificial aid except a big stone and a rope. Some of these men can stay down as long as four minutes, but it is killing work, and not many can stand more than a few years of it.

The invention of the first diving apparatus is generally ascribed to that wonderful old monk, Roger Bacon; but this is mere tradition, and the first reliable account of a diving-bell refers to the Aquatic Kettle used by two Greeks before the Emperor Charles V at Toledo in Spain. This evidently resembled the modern diving-bell, except that it was not fitted with means for replenishing the air-supply, and therefore its occupants could only remain

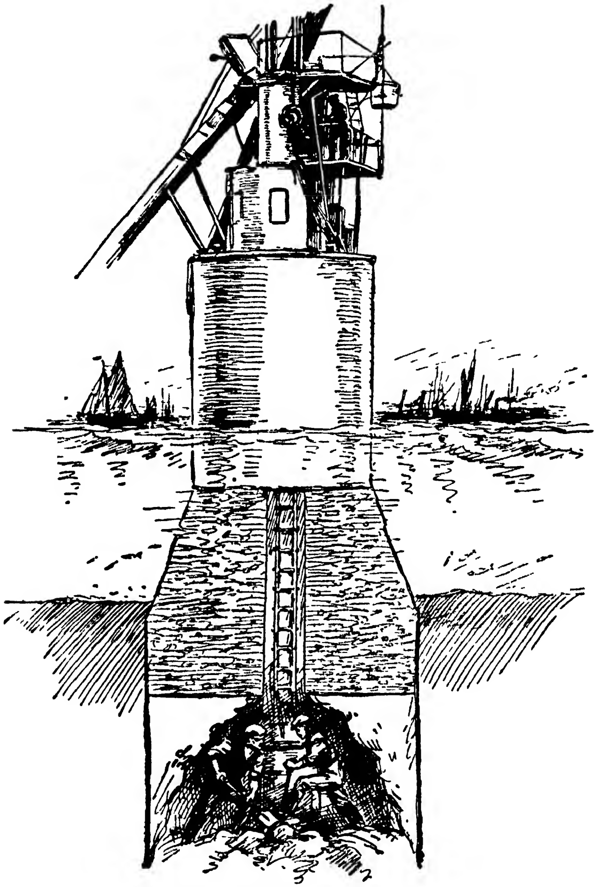
down for a very short space of time; when the air had become too foul to breathe they had to signal to be pulled up again.

The first attempt to give the divers a constant supply of air was in the diving-bell invented by Dr Halley in the reign of George I of England. This was built of wood loaded with lead along the bottom edges, and had stout glass windows fitted in the top. Casks filled with air and weighted to make them sink were let down at intervals in order to give the divers a fresh supply. As these were lowered past the bottom of the bell, the men inside pulled them in and turned them over so as to let the air escape inside the bell.

PEARL-DIVER IN THE PERSIAN GULF

A little later John Lethbridge constructed a real diving-bell—the first to be made of a bell shape. This, before sinking, was filled with compressed air by means of a large bellows, and two men could work in it for half an hour. Many attempts were made during the 18th century to improve the diving-bell, and one or two inventors tried to build diving-suits. But, since rubber was still unknown, they were forced to use leather instead, and of this material it is impossible to form a satisfactory diving-suit. The air-pipes, too, had to be made of leather—a purpose for which this material was equally unsuited.

Smeaton, one of the greatest engineers of the 18th century, was perhaps the first to make a diving-bell which was constantly supplied with air by means of a pump.



A CAISSON

It is known that he used such an invention in 1779 for repairing the foundations of a bridge in Northumberland. Nine years later he was busied in constructing the harbour of refuge at Ramsgate, and here he built a diving-bell of solid iron weighing two and a half tons, which sank by its own weight. In 1813 Rennie used a still larger bell, five

tons in weight, of similar construction. Air was supplied by a pump through a two-and-a-half-inch hose, and was admitted into the bell through a valve; this was really the first of modern diving-bells. Throughout the 19th century various designers built bells of ever-increasing size, until the one constructed for fixing the huge blocks used in the foundation of the breakwater of North Wall Harbour at Dublin was no less than twenty feet square, its weight being over eighty tons. The workmen entered by means of a wrought-iron shaft and air-lock, so it was really more of a caisson[1] than a mere diving-bell. Our sketch shows one of the caissons used in 1925 in the construction of a temporary bridge during the rebuilding of Waterloo Bridge, London.

The diving-bell is still used for certain kinds of work, and more particularly when two or three men have to work together under water; but it is at best a somewhat clumsy contrivance, and now that the diving-suit has reached such perfection the bell has been largely superseded.

The modern diving-suit depends for its usefulness on the helmet, which was invented by Augustus Siebe in the year 1829. As first made, the helmet was nothing more than a miniature diving-bell which covered the diver's head. The canvas jacket, which was fastened to the helmet, was left open at the bottom, and the air pumped down into the helmet for the diver's use escaped under the weighted edges of the jacket. The result was that at all times the water was only a few inches below the mouth of the unhappy diver, and he dared not stoop. It was another ten years before Siebe got rid of the dangers attending the use of this suit by inventing the closed suit as at present worn.

It will perhaps be interesting to describe how a diver dons his armour-like costume before descending into the

[1] A large watertight case used in laying foundations under water.

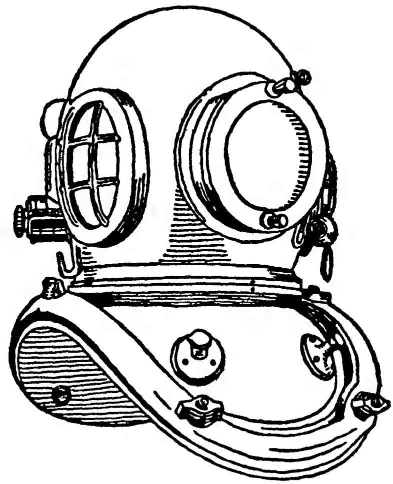
depths of the sea. First, then, he takes off his coat, hat, and boots. He next puts on, one after another, three pairs of immense woollen stockings. Over his head he draws two heavy white guernseys, and he wears also two pairs of thick drawers, both made of the warmest wool. However hot it may be on the surface, the depths are always cold. Snugly buttoned up in his thick woollen undergarments, the diver is then ready to get into the diving-suit—an uncanny-looking affair, which is body, legs, and feet in one piece, and which has the singular merit of fitting equally well a big man or a little one.

It is made of solid sheet indiarubber placed between specially prepared double-tanned twill, and is fitted with indiarubber cuffs which are so made that they form an absolutely watertight joint at the wrists. The wearer's hands and wrists must be well soaped before he puts his hands through the sleeves. The collar is made double. The inner part of waterproof twill is fastened round the neck, while the outer, of thick rubber, has screw-holes, matching similar holes in the breast-plate to which it is fitted.

The breast-plate is made to fit over the shoulders, but is large enough to allow plenty of room for a free movement of the diver's arms; it is clamped to the rubber top of the dress so as to be absolutely watertight, and is fitted with brass knobs over which cords pass from two hooks, one on each side of the helmet, for slinging the two leaden weights already mentioned. After the breast-plate is fitted, the diver puts on his boots, which are made of leather, gun-metal, wood, and lead. Each weighs sixteen pounds, and is of enormous size.

Now at last the diver is ready for his helmet, which is by far the most wonderful part of the whole kit. Like the breast-plate, it is made of copper with gun-metal fittings which connect so cleverly with the breast-plate that only one-eighth of a turn is required to make the

joint absolutely watertight. To admit light, the helmet is fitted with two oval windows in the sides of thick plate-glass, set into brass frames. There is another glass in front, also set in a brass frame, which screws in and out so that the diver may readily obtain fresh air upon coming out of the water. At the back of the helmet is the gun-metal inlet valve to which the air-pipe is connected, and which is so clever an invention that while air can enter the helmet it cannot possibly return or escape. In case of accident to the pump or the air-pipe, enough air remains in the helmet to allow the diver to return safely to the surface. Another very clever device with which all divers' helmets are fitted is that of air-conductors from the inlet valve; these, by carrying air across the glasses, prevent them from being clouded by the wearer's breath.



THE DIVER'S HELMET

The air-pipes used with a diving-suit are tested up to a pressure of no less than two hundred pounds to the square inch, and accidents from the failure of diving apparatus made by well-known firms are almost unknown. The most modern suits are fitted with telephones, so that the diver can at any moment communicate with those above. Previously he had to rely entirely upon signals made by pulls upon the life-line.

One of the most useful inventions for under-water work is the diving-suit invented in 1880 by Mr Fleuss, which makes its wearer independent of air supplied from above. In a strong copper cylinder fixed upon his back the diver

carries a supply of compressed oxygen regulated at will by a screw-valve. The carbonic acid exhaled by the wearer is absorbed by caustic soda contained in a separate receptacle, while the nitrogen of the air mixes afresh with the oxygen and can be breathed over and over again.

In this suit, which weighs less than thirty pounds, the diver can remain below water for at least two hours, and the invention is invaluable for all who have to work in flooded mines or in any place where there is danger of the air-pipes being entangled among timbers or other *dêbris*.

One of the latest devices to aid the diver is an outfit, very like a sack with a special battery attached, invented by Dr Draegs for restoring a diver who has become unconscious or has fallen victim to the pressure sickness to which divers who work at great depths are liable.

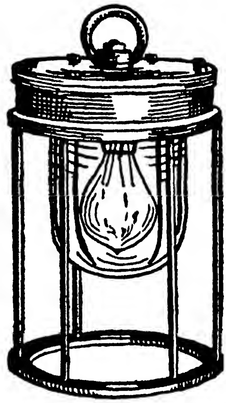
The diver naturally finds it difficult to see under water, especially in Northern seas, where the water is usually so thick that, even at a very moderate depth, the darkness is almost complete. The modern diver is well provided for. He has at his command powerful electric lights supplied with current from the boat above. When working in enclosed spaces he uses an electric lantern provided with an accumulator.

Early in 1924 a young Italian inventor, Professor Leandro Guglielmotti, patented a new invention which, if it justifies the claims made for it, will be a most valuable aid in all sorts of submarine work. It is a process by which the law of refraction is overcome and which enables men to see under water. "The first idea of this discovery," says the Professor, "came to me in 1916, when submarine warfare was at its height. I realized how helpless submarines became once they were totally submerged, and it occurred to me how greatly their strategic power would be increased if means could be found to enable the crews to see under water. The law

DIVER AT WORK ON SUNKEN WRECK USING
OXY-ACETYLENE BLOW-PIPE
G. Henry Evison

of the refraction of light presented an almost insuperable obstacle, but after long studies and patient research I devised a method by which a line of light could be made to pierce the water, yet at the same time be invisible to any aircraft watching above."

Guglielmotti's new invention, it appears, projects through the water shafts of invisible light which will illuminate any body coming in the direction of their rays up to a distance of three hundred yards and to a depth of about fifty feet.


DIVER'S ELECTRIC HAND-LAMP

Another Italian whose under-water inventions have brought him fame is Cavaliere Pino, the deviser of the hydroscope. Pino, born at Chiampo in Venetia, was left an orphan at an early age, and from boyhood devoted his spare time to devising new inventions. Finding that his relatives looked upon him as a lunatic, he ran away from home and went to Genoa, where he got work in the Royal Bread Factory. One day the manager of the bakery found the boy busy during his dinner-hour with pencil and paper, and asked him what he was drawing. Young Pino explained that he was designing a new sort of submarine boat, and so interested the manager that the latter gave him an introduction to a firm of engineers, and himself advanced money to help build the new craft.

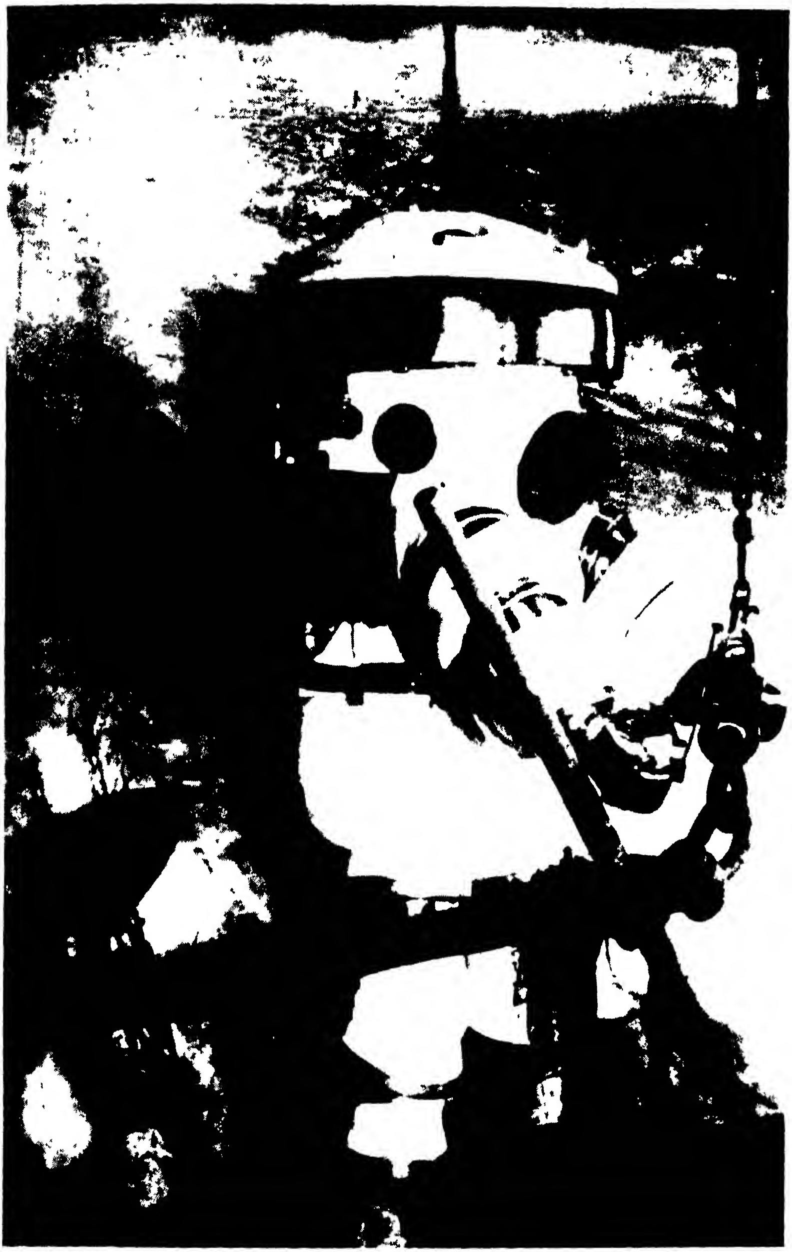
Pino was only twenty-four years old when the plans for his new submarine were complete. The one point on which he was uncertain was the breathing apparatus he had designed, so, in order to test it, he had a metal box made, and in this, after it had been hermetically sealed, he had himself lowered to the bottom of the Gulf of Genoa. In case of danger he could make a signal, when his friends were to pull his metal coffin to the surface.

Minutes dragged by, but no signal came, and at last the watchers could bear the suspense no longer and hauled up. When they opened the lid, there was Pino, very much alive, but very angry. "I gave no signal," he exclaimed. "Why could you not have left me? I was just beginning to enjoy myself." In Pino's submarine it is said that a man can descend to a depth of five hundred feet, or more than twice the depth which can be reached in the ordinary diving-suit.

Pino's hydroscope consists of a long tube fitted with various lenses so arranged that objects lying at the bottom can be reflected upon a screen on the deck of the ship that carries it. Pino has also devised a machine called an 'elevator,' by means of which sunken objects can be grappled and raised to the surface. Since it is calculated that the average monthly loss of vessels sunk in all the seas exceeds 50,000 tons, the value of these inventions should be enormous.

The large number of ships sunk during the Great War has led to a great increase in diving all over the world. A diver receives, besides his wages, a commission upon the objects which he salves, so that some earn considerable sums. But he must start young and be thoroughly sound in wind and limb. A man with weak heart or nerves is useless as a diver.

Apart from ship salvage, divers find employment in pearl-fishing and in gathering sponges. Since all the shallower beds of pearl-oysters have been skinned long ago, most of the work at present is done in diving-suits, and at depths varying from sixty to a hundred and ten feet. While a diver can remain at a depth of forty or fifty feet for two hours on end without inconvenience, he cannot endure depths of over a hundred feet for more than about twenty minutes at a time. Under high pressure the blood absorbs air quickly, and air-bubbles may pass into the heart, which causes death. A diver who has



DEEP-SEA DIVER ENTRENCHED WITHIN CASTLE WALLS

Photo Keystone View Co

THE STUDIO AT READING OPENED BY TALBOT AFTER HE HAD PATENTED HIS CALOTYPE PROCESS

From the collection of the Fox Talbot Historical Experimental Apparatus in the Museum of the Royal Photographic Society, London

been at, say, a hundred and fifty feet for twenty minutes must come up very slowly, taking fully twenty minutes in his ascent. Otherwise he will probably contract diver's palsy and die.

Pino's submarine is not the only device enabling the diver to work at depths beyond what is possible with the ordinary diving-suit. Another more recent equipment gives the impression of a castle tower. Entrenched within its walls the diver can defy the air-pressure of five hundred feet and more. He is lowered and raised again by means of a derrick or crane.

Divers are constantly at work building or repairing harbour works or breakwaters, and every large dock has its own divers. One of the strangest tasks ever performed with the aid of a diving-suit was the saving of Winchester Cathedral. Eight centuries ago the eastern arm of this cathedral was built upon foundations made of trunks of trees laid in the soft soil. These gradually sank under the immense weight of masonry, and it was found necessary to underpin the building with blocks of concrete. The whole of this work had to be done under water, and nearly all of it was done by one man, Mr W. R. Walker. For four and a half years he was constantly busy burrowing under the cathedral, and the whole time working in pitch darkness, for the water, black with peat, was too dark to allow the use of electric light.

CHAPTER XIV

PHOTOGRAPHY

Joseph Niépce's Heliographs—How Lucky Accidents aided Daguerre—Fox Talbot's Calotypes—Photography's Value to Science.

COUNTLESS years ago man must have noticed the action of sunlight upon his skin—how it tanned him in summer, turning him brown wherever the rays struck full upon his unprotected body. Later he discovered the bleaching action of sunlight, and used it for making white his early woven fabrics. No doubt he early recognized also the power of the sun in spring and summer upon the vegetable world—how it made grass and wheat sprout and brought out the green leaves upon the trees.

It was not, however, until modern chemistry began to supersede the alchemy of the Middle Ages that the action of sunlight upon various chemical compounds was realized. Some of these actions are very curious and interesting. For example, if equal volumes of chlorine and hydrogen gas are mixed together in the dark, they will remain without change. But the instant that the glass flask containing the mixture is exposed to the direct rays of the sun, the two gases unite with a tremendous explosion, blowing the flask to atoms. Sunlight has also a strong action upon various compounds of silver. Take a moist chloride of silver: this remains white as long as it is kept in the dark, but the very instant it is exposed to sunlight it takes a violet hue which rapidly becomes black.

So long ago as 1801 Sir Humphry Davy and Thomas Wedgwood used nitrate of silver for the purpose of making copies of objects the shadows of which were thrown upon

white paper soaked in nitrate. But Davy did not know of any means for 'fixing' the shadows, so it would not be correct to call his work photography. Yet Davy realized that such a means or agent was needed, for he wrote at the time: "Nothing but a method of preventing the unshaded portions of the delineation from being coloured by exposure to the light is wanting to make the process as useful as it is elegant."

Now, if asked who was the inventor of photography many would doubtless answer that it was the Frenchman Daguerre. It is true that Daguerre was the first man to produce anything resembling the modern photograph, but he was not the first to make a permanent sun picture. This honour belongs to two brothers named Niépce, who lived at Chalon, a town on the river Saône in Central France. Both had scientific tastes; and since Joseph, the elder of the two, owned a good farm, he and his brother had leisure to try all sorts of experiments. In 1806 they produced a model locomotive worked by heated air, which was reported upon by the French Institute.

About this time the new invention of lithography had just been introduced into France. Lithography is a method of printing from stone, and was invented by Aloys Senefelder in the year 1796. He patented his process in 1800, and it spread rapidly, all the best coloured pictures being reproduced by this process. Quarries fit to yield lithographic stone were eagerly sought for, and Joseph Niépce, among others, entered the search. He found some stones which at first seemed suitable, but, after trying them, had to cast them aside as useless. Then the idea came to him that possibly a sheet of polished steel might be substituted for stone, and he began experiments.

One day, when busy with these labours in his little workshop, it happened that a broad beam of sunlight streaming in through the open door produced a reflection

of his own face in the polished plate over which he was bending, and the idea came to him that if he could only imprint such images by the mere action of sunlight he would have secured an invention fàr more important than that of Senefelder.

Joseph had at that time no knowledge whatever of the experiments of Davy and Wedgwood, and certainly could not have appreciated the enormous difficulties that lay in his way. Yet from that minute he devoted his life to the solution of the problem, and his whole mind was absorbed in the one question of whether to-morrow's sun would produce any effect upon the new compounds which he was constantly inventing.

After a while came the knowledge that a certain black resinous substance, known in the Arts as bitumen of Judea, on being exposed to the sun rapidly turned white. Already Joseph was aware that preparations of silver blacken in the sun's rays, and, acting upon these two facts, he tried a most singular method of reproducing engravings. First he varnished the reverse side of a print so as to make it transparent, then he placed this on a leaf of metal coated with bitumen. The darker parts of the picture obstructed the rays of light, while those which were lighter allowed them to pass, and acted upon the bitumen. In this way Joseph Niépce obtained a perfect reproduction of the design in which the lights and shadows retained their natural position. By plunging the leaf of metal into a preparation of essence of lavender, the inventor found that he was able to 'fix' his picture, and this was actually the first permanent sun picture ever made.

From this kind of copying Joseph went on to tackle the problem of fixing images obtained by the camera-obscura, and at this he worked steadily for ten years. His chief agent was still bitumen spread upon a copper plate silvered over, but the bitumen required a very long time—no less than ten hours—to receive impressions.

So long an exposure to direct sunlight was, of course, almost impossible, for not only did clouds interfere, but the sun's position was constantly changing. Yet in 1824 Joseph Niépce did actually produce real photographs—'heliographs,' he called them; and considering the difficulties with which he had to contend, these were really wonderful productions.

Unknown to Joseph, there was at this time a man living in Paris who was engaged in similar researches. This was Louis Daguerre, a scene-painter, and well known because of his invention of that kind of scenic exhibition known as the diorama. It was the special researches which Daguerre had been obliged to make into the effects of light and shade which had suggested to him the idea of trying to fix the beautiful pictures obtained by the camera-obscura.

In 1827 there came to Daguerre's ears news that an obscure farmer in a country village had succeeded in solving this difficult problem, and he at once posted off to interview Niépce. The latter, stiff at first, soon thawed, and the two went into a sort of partnership. Daguerre substituted for the pitch which Niépce had been using a resin obtained by distilling essence of lavender, but instead of washing the plate in the essence he exposed it to the action of a vapour derived from it. This quickened matters somewhat; yet even so, seven hours at least were required to obtain a picture.

Then came one of those lucky accidents which have so often aided the quick-witted inventor. Before his association with Daguerre, Joseph Niépce had endeavoured to strengthen his plates by exposing them to the fumes of sulphur and iodine. It happened one day that a spoon left by accident on an iodized silver plate left a distinct impression of itself, and, noticing this, the inventor substituted iodine for the resinous substance hitherto used by them. Iodine, they found, gave to the silvered plates

an exquisite sensibility to light, and the second great step toward the perfect sun picture was taken. By this means the time of exposure for outdoor objects was reduced from seven hours to three minutes, while interiors could be photographed in about half an hour.

In 1833 Joseph Niépce died, at the age of sixty-three. He was still poor and unknown, and had spent his whole life and nearly all he possessed in pursuit of an invention which he did not live to see fully perfected. The least that we of this age can do is to give the patient worker full credit for being the world's first photographer.

Left alone, Daguerre carried on the work. Although he had succeeded in quickening the work of the sun, the impressions were still faint, and he still had no satisfactory method of developing his pictures. Again accident came to his aid. One evening Daguerre placed in a cupboard one of his silver iodine plates that had been exposed, and left it overnight. In the morning, on taking it out he was amazed to find that a picture had been developed on this plate. That day he exposed another plate, and, leaving it in the same cupboard, beheld next morning again a picture. How or why this had happened was beyond Daguerre's imagination, but he set himself methodically to find out. In the cupboard were a quantity of chemicals of one kind and another, and Daguerre believed it was the vapour from one of these which was responsible for the seeming miracle. At last it became certain that it was a dish of mercury which had wrought the change, and so Daguerre discovered that he could develop an exposed plate by placing it in the dark, face down, over a dish of warmed mercury. A little later came the discovery that it was possible to fix the image satisfactorily by dipping the plate in a bath of sodium thiosulphate, which is, in fact, the ordinary 'hypo' so well known to all photographers, amateur as well as professional.

Daguerre then made an effort to form a company to develop his new process, but was unable to do so. The long exposures still required, and the high cost of making the sun pictures, were against the commercial success of the new invention. His country, however, recognized the merit of Daguerre's work, and granted him a pension of six thousand francs a year.

It is a very interesting point that Samuel Morse, the inventor of telegraphy, learned the process of photography direct from Daguerre himself, and upon his return to New York in 1840 produced the first photograph ever taken in the New World.

Meantime, in England, William Henry Fox Talbot had been busy in researches of his own, and in 1839, just six months before Daguerre published the results of his efforts, read a paper before the Royal Society on what he called 'A New Art of Photogenic Drawing.' This was his process: first, soaking a sheet of writing-paper in brine, he dried it, then dipped it in a solution of nitrate of silver, thereby changing part of the nitrate to chloride. Paper so treated becomes sensitive to light, so that when a leaf, for example, is laid upon it between two plates of glass, and sunlight is allowed to act upon it, the paper goes black, except where it is covered, and thus a perfect outline of the leaf is obtained. It was Talbot who invented the terms 'positive' and 'negative' still used in photography. Two years later he invented an improved process, which he called the 'Calotype.' The paper negative was rendered translucent by means of wax; when placed in front of a piece of sensitized paper, prepared in the same way as that used for producing the negative, a positive print was obtained. Thus Fox Talbot must be honoured as the discoverer of the means of producing any number of prints from an original negative.

By 1847 glass plates had come into general use. Niépce de St Victor, a nephew of Joseph Niépce, had discovered

a method of coating a glass plate with egg albumen, to which iodide and bromide of potassium and common salt had been added. Before exposure this plate was immersed in a nitrate of silver bath, which rendered it sensitive to light, and after exposure was developed with gallic acid and then fixed.

A few years later, in 1851, Frederick Scott Archer introduced collodion, which is a solution of cotton in nitric and sulphuric acid afterward dissolved in ether. This gave a transparent substance which could be used to coat glass plates, and the process, known as the ' wet plate,' lasted until it was superseded by the gelatine dry plate. Ever since those early days, not a year has passed without fresh inventions and developments in photography. Perhaps the most important have been the invention of optical glass and of new forms of photographic lenses. I shall have more to say of these subjects in a later chapter.

In concluding his address to the Royal Photographic Society in 1921, the President, Dr G. H. Rodman, said:

" The introduction, in 1885, of films to replace glass and save weight, and the production, in 1903, of non-curling celluloid film, so wound on rollers as not even to require the use of a dark room for loading the camera, has had a very decided effect in the popularizing of photography, and it is chiefly due to this production of the Eastman Company that photography has been taken up by the masses. Finally, the obtaining of photographs in natural colour, rendered possible by the Autochrome process of Lumière in 1907, and in the Thames, the Paget, and the Dufay screen processes, enables the worker to secure representations on glass of objects in natural colour. The names of Lippman, Ives, and Sanger Shepherd are those of men who will long be remembered for the part they have played in the rendering of colour by photography.

"What further developments there will be I do not venture to predict; but I feel sure, with the vast body of men now engaged on photographic work, that we shall have advances equal to, if not excelling, those that I have been privileged to bring before your notice this evening. . . . When we consider what was required in the days of the wet collodion plate, so much in use between 1851 and 1870, how that plate had to be sensitized on the spot, and developed as soon as removed from the camera, and for these reasons when work was done at a distance from the photographer's dark room it was necessary to carry sensitizing baths and developing and fixing solutions, and to go out with a dark tent in which the plate could be manipulated, we must recognize the great change that has taken place in photographic procedure. Compare, for example, the ease of the use of the modern-day vest-pocket camera, with its roll film so easily inserted and removed after use, and capable of being exposed at, say, the South Pole, and then sent thousands of miles prior to development, with the difficulties which the landscape photographer of sixty years ago had to surmount, when he had to include in his armentarium a hand-cart on wheels for the transport of his developing tent and solutions, and travel with an assistant who played the part of a beast of burden! I cannot imagine a more graphic illustration of these points than that afforded by the comparison of the modern vest-pocket Kodak camera, provided with its highly corrected focusing Cooke lens of English manufacture, fitted with a reliable time and instantaneous shutter, with its autographic recording device, and not even requiring the use of a dark room for the insertion and subsequent development of its roll film. With such an instrument, capable of producing very excellent results, and weighing, as it does, about twelve ounces, it is not surprising that the practice of photography has become so popular."

Photography, at first looked upon merely as a means for making rapid and truthful portraits, has become much more than a popular hobby. Quite apart from its enormous value in the illustration of newspapers and books, it is of supreme importance to scientists, including astronomers. By using the camera in conjunction with the telescope, the most remarkable photographs have been obtained of celestial objects, and thus the details of a vast field of the heavens have been revealed as only the camera can show them.

The human eye tires and is easily deceived, but the eye of the camera is infallible, and it registers images which no human eye can behold. It has already proved to us that the number of stars is at least double that previously suspected. The face of the moon, the blazing atmosphere of the sun, the moons of our planets—all these have been faithfully recorded by the camera, and the work of its watchful eye never ceases.

CHAPTER XV

MODERN PRINTING

How *The Times* was produced by Steam—Moulding and Stereotyping—Type-setting Machinery.

FOR hundreds of years the methods of printing which had been invented in the 15th century remained almost unchanged. The type was set by hand and printed in flat presses, and inked by means of large round pads of leather stuffed with wool. These balls were as much as twelve inches in diameter, and the apprentice whose task it was to spread the ink upon the type used two of them, dabbing one against another and working them against the face of the type with a twisting motion. It was a slow operation and a troublesome one, and required much practice before the operator became perfect at his task. The boys who did the work were known as printers' 'devils,' no doubt because the ink spread over their hands and faces gave them a distinctly impish appearance.

The first improvement, and one which eventually opened the way to the invention of the modern printing machine, was the substitution of a roller for these balls. The roller was a cylinder made of hard wood and covered with a composition of glue and treacle, which was both soft and elastic and would easily take up the ink. The presses, too, were improved. The first were built of wood with screws, made like the old-fashioned cheese press. Late in the 18th century iron presses were substituted for the old wooden ones. Earl Stanhope made such a press in 1798, and this was provided with levers which pressed down the 'platen' (that is, the flat plate

which overlies the paper and receives the pressure) with more force than the old hand-press. His new press was found to give a much clearer impression of the type than the older methods.

The hand-press, worked by skilled men, gave at most two hundred and fifty impressions per hour, and it was becoming more and more difficult for newspapers, even with the limited circulation of those days, to satisfy their readers' demands in the way of circulation. Also, as we have already seen, steam-power was rapidly coming in to work all kinds of machinery, and it was evident that it could be only a matter of time before printing would be done by machinery.

The first attempt to effect this was made in the year 1790 by Nicholson, who patented a rotary printing-press, but it does not appear that he ever constructed one. Twenty-three years later, in 1813, Bacon & Donkin took out a patent for another printing machine, also on the roller principle, but this was not a success. Then came the invention of Cowper, who first had the idea of taking a cast of the type and bending the cast round a cylinder. Cowper was really the first of modern printers, but he was forestalled by Frederick Koenig, who, in 1814, set up steam-driven printing machinery for Mr Walter, proprietor of *The Times* newspaper.

Koenig was a Saxon who in 1802 devised an improved printing machine with a movable carriage, inking rollers, and a new method of taking off the impression by flat pressure. As he could find no one in Germany to take up his new invention he came to England, where he worked at the printing office of Richard Taylor in Shoe Lane. Taylor introduced him to Thomas Bensley, a well-known printer in Bolt Court, Fleet Street, and in 1807 Koenig and Bensley went into a sort of partnership. This gave Koenig a chance to prepare plans of an improved machine, but it took him three years to perfect

it and make a working model. This was shown to Mr Walter, but at first he refused to have anything to do with it.

Koenig, however, constructed his machine, and it was set up in April 1811, when *The Annual Register* of that year was printed on it. This machine still had the old flat platen, but now it occurred to Koenig to use a cylinder instead. Two other well-known London printers joined Koenig and Bensley in the manufacture of Koenig's new machines, and in 1812 one was made which would take off impressions at the rate of eight hundred an hour.

Again Koenig approached newspaper proprietors, Mr Perry of *The Morning Chronicle* and Mr Walter of *The Times*. Mr Perry would not even go to see the new machine; but Mr Walter, though he had refused Koenig's first machine five years earlier, decided to see it. He was so deeply interested that before he left the premises he had ordered two of the machines.

The parts were prepared in a factory in Whitecross Street, and taken with the greatest secrecy to the premises of *The Times* in Printing House Square. Yet even so, rumours got afloat about the new machine, and the printers vowed a terrible vengeance upon the alien inventor who threatened their craft.

Excitement steadily increased, for it was said that the new machines were being put together. A general strike was threatened. One night the whole staff were told to wait in the press-room because important news was expected from abroad. That was the night of November 28, 1814. At six o'clock next morning Mr Walter, who had been watching the machines all night, walked into the room and quietly announced, "*The Times* has been printed by steam." He added a warning that if any attempt was made at violence a force of police was ready outside, but that, if the men remained peaceable, their wages would be paid as usual. That paper, the first

ever printed by steam, tells its own story in the following words:

> Our journal of this day presents to the public the practical result of the greatest improvement connected with printing since the discovery of the art itself. The reader of this paragraph now holds in his hand one of the many thousand impressions of *The Times* newspaper which were taken off by a mechanical apparatus. A system of machinery almost organic has been devised and arranged, which, while it relieves the human frame of its most laborious efforts in printing, far exceeds all human powers in rapidity and dispatch. That the magnitude of the invention may be justly appreciated by its effects, we shall inform the public that after the letters are placed by the compositors, and enclosed in what is called the 'forme,' little more remains for man to do than to attend upon and watch this unconscious agent in its operations. The machine is then merely supplied with paper, itself places the forme, inks it, adjusts the paper to the forme newly inked, stamps the sheet, and gives it forth to the hands of the attendant, at the same time withdrawing the forme for a fresh coat in ink, which itself again distributes, to meet the ensuing sheet now advancing for impression, and the whole of these complicated acts is performed with such a velocity and simultaneousness of movement that no less than 1100 sheets are impressed in one hour. That the completion of an invention of this kind, not the effect of chance, but the result of mechanical combinations, methodically arranged in the mind of the artist, should be attended with many obstructions and much delay may be readily admitted. Our share in this event has, indeed, only been the application of the discovery, under an agreement with the patentees, to our own particular business; yet few can conceive, even with this limited interest, the various disappointments and deep anxiety to which we have for a long course of time been subjected.
>
> Of the person who made the discovery we have little to add. Sir Christopher Wren's noblest monument is to be found in the building which he erected: so is the best tribute of praise which we are capable of offering to the inventor of the printing machine comprised in the preceding description, which we have feebly sketched, of the powers

> and utility of his invention. It must suffice to say further, that he is a Saxon by birth, that his name is König, and that the invention has been executed under the direction of his friend and countryman, Bauer.

On December 3, 1814, *The Times* speaks again of its new methods:

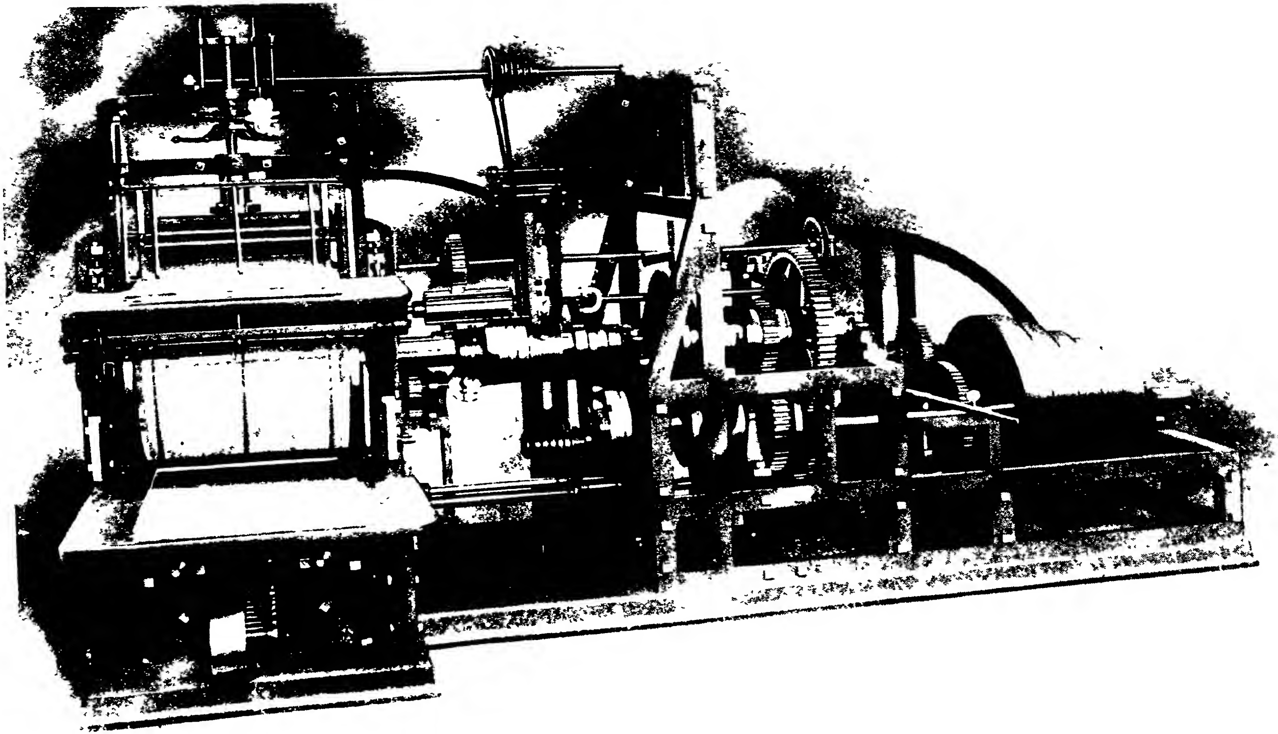
> The machine of which we announced the discovery and our adoption a few days ago has been whirling on its course ever since with improving order, regularity, and even speed. The length of the debates on Thursday, the day when Parliament was adjourned, will have been observed; on such an occasion the operation of composing and printing the last page must commence among all journals at the same moment; and starting from that moment we, with our infinitely superior circulation, were able to throw off our whole impression many hours before the other respectable rival prints.

Koenig, it is true, was a German, but his partners, without whose money and help the new machine could never have been made a success, were English. Yet we must give credit to Koenig as the real inventor of the first practical machine for printing by steam. He afterward returned to Germany, where he started a factory and made a large number of his machines for various Continental firms. Like so many other inventors, Koenig suffered from his early struggles, and died at the comparatively early age of fifty-eight. The firm founded by him, Koenig & Bauer, is still one of the most active makers of printing machines, and our illustration shows one of their latest rotary presses for printing magazines, etc., on varying sizes of paper. The earlier machines printed upon a flat bed, and the introduction of the cylinder or rotary press increased the output four or five times.

While Koenig was busy with his steam-printing machinery for newspapers, the Englishman Cowper, already mentioned, was working upon a new machine for printing wall-papers. This was so great a success that it was

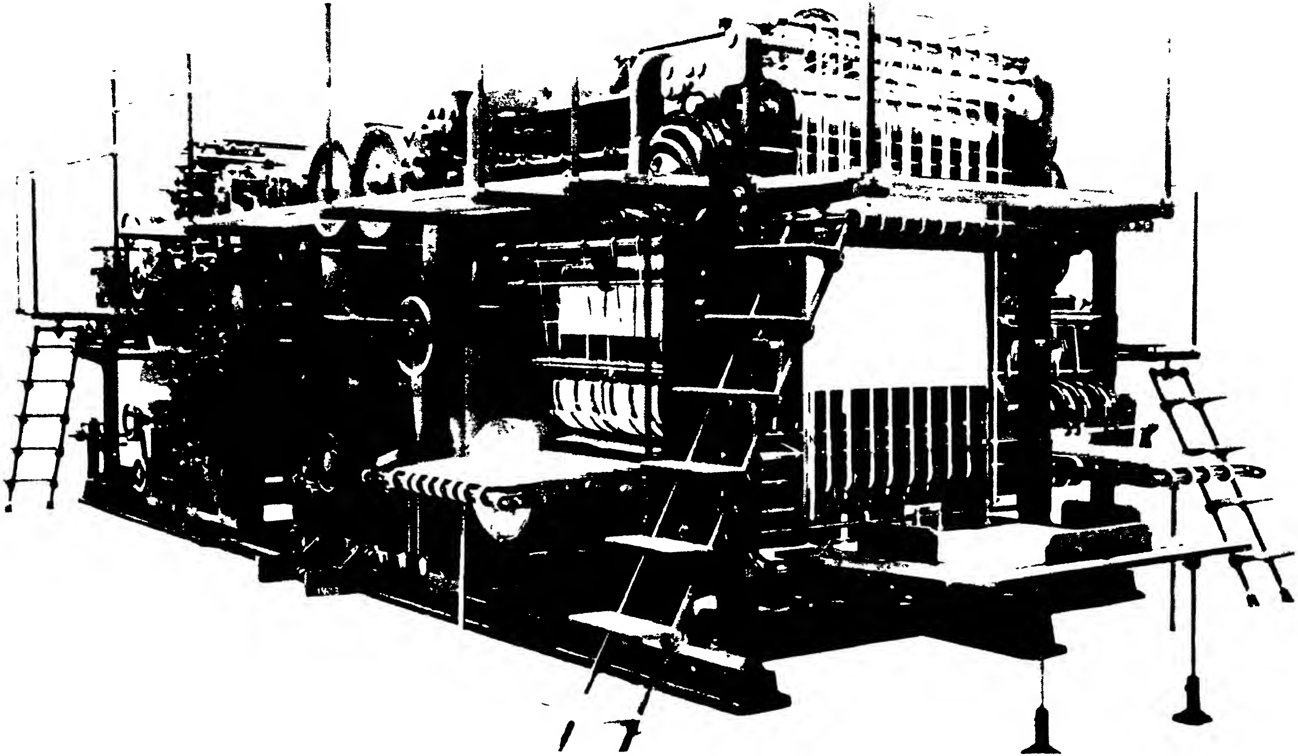
adapted for printing the one-pound notes then issued by the Bank of England, and over four million notes were printed, each in two colours. Cowper went into partnership with Mr Applegath, and the two proceeded enormously to improve upon Koenig's early machine. They produced a four-cylinder machine capable of printing between four and five thousand sheets an hour. The firm of Cowper & Applegath flourished for many years, and in 1848 had produced an eight-cylinder machine which would print as many as ten thousand sheets. Then there came to England the first of the printing machines made by the famous New York firm of Richard M. Hoe, and between 1856 and 1862 a number of great English newspapers fitted their works with these remarkable machines. The two ten-cylinder Hoes purchased by *The Times* were driven at the rate of thirty-two revolutions per minute, and turned out sixteen thousand copies in an hour. I might mention, by way of comparison, that the modern printing machines turn out copies of an eight-page newspaper at the amazing speed of over two hundred thousand an hour; and these are not only printed by the machine, but also neatly folded.

Speeds such as these would have been impossible but for the invention of stereotyping. So long ago as 1730 an Edinburgh goldsmith named Ged invented a method of stereotyping. He used liquid stucco, which he poured over the types, and this, when solid, gave a perfect mould. Into the mould molten metal was poured, and a plate was thus produced which was a duplicate of the type itself. Ged obtained the privilege of printing Bibles and prayer-books after this method, and hoped to make a fortune. Like many other unlucky inventors, however, he forgot the hatred inspired in workmen by any new labour-saving device. His compositors battered and spoiled his stereotype plates, and the unfortunate Ged was ruined and died in poverty.



THE FIRST STEAM CYLINDER PRESS INVENTED BY FREDERICK KOENIG, AND USED IN PRINTING "THE TIMES"

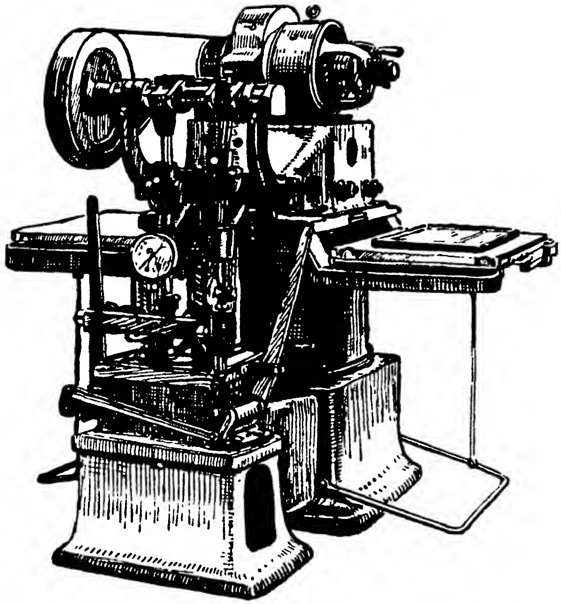
[*See p.* 157]



MODERN ROTARY PRESS MADE BY MESSRS KOENIG AND BAUER, WURZBURG

[*See p.* 159]

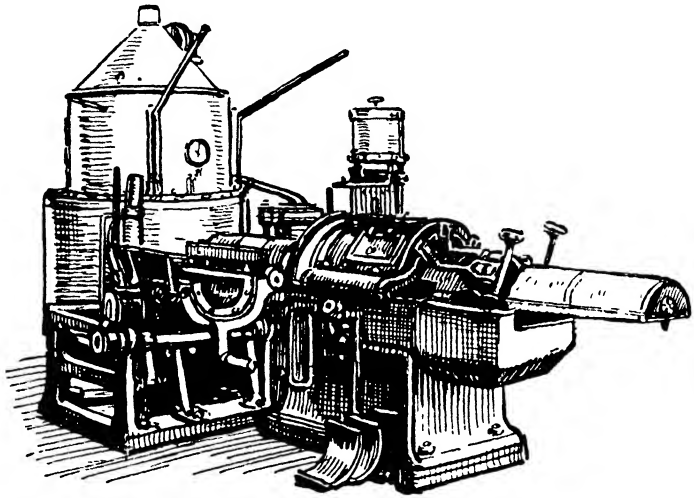
But an invention which is of enormous importance to mankind cannot be destroyed by ignorant tyranny. It was revived in Scotland, France, Germany, and America, and Lord Stanhope, to whom printing owes so great a debt, made experiments with it between 1790 and 1800. Yet it was not for another half-century that stereotyping came to its own. The inventor of the modern method was an ingenious Italian named Dellagana, who discovered that *papier maché* (paper pulp) could be used for making matrices or moulds. Dellagana took his invention to Mr Walter, and, just as *The Times* was the first newspaper to be printed by steam, so it was the first to use the modern method of stereotyping.



AUTOMATIC PRESS FOR MAKING AND DRYING MOULDS

At first each column of type was separately 'stereoed,' but soon it was found that an impression could just as easily be taken of an entire page. The impression is taken in *papier maché,* and rapidly dried on the same press, an example of which, from a model manufactured by Messrs Koenig & Bauer, is shown in our illustration. The mould is then placed in a casting-box, which is either flat or curved to the same radius as the cylinder of the printing-press, and liquid metal is poured into it. Thus a metal plate is obtained which, when trimmed, is ready

for printing from. The advantages of such a plate are easily seen, for not only is the plate solid and perfectly shaped, either to a flat bed or to the drum or cylinder, but also any number of casts may be taken from the same mould. This makes it possible to have several machines printing the same plate at the same time, with no extra labour in the composing-room. The plates, when



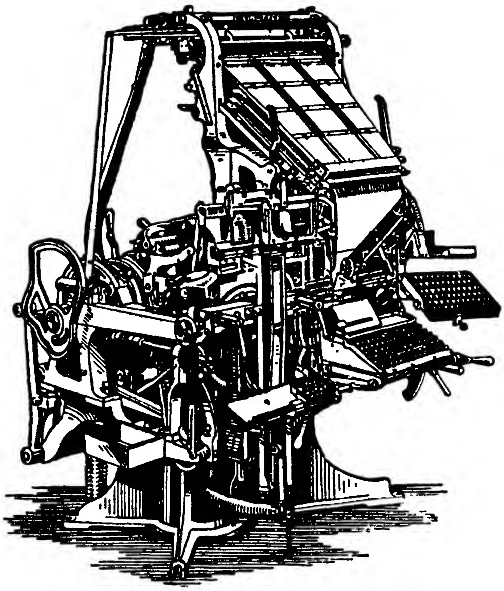
MACHINE FOR MAKING STEREOTYPE PLATES

finished with, can be melted and the metal used again and again.

Printing machines have been constantly improved, and never a year goes by without further improvements. To-day the machine-room of a great newspaper provides one of the most interesting sights in the whole range of human industry.

As methods of printing improved, and as the spread of education and the increase of population sent up the circulation of newspapers to figures previously undreamed of, owners of newspapers found themselves confronted by another problem. This was to set up type as rapidly as the printing machines required. It was no use being able

to print papers at the rate of twenty to fifty thousand an hour if the compositor could not set up the type in a proportionately short space of time. So inventors everywhere began to work to produce a machine which could set type quicker than by hand. Hundreds of patents were taken out, but it was not until Ottmar Mergenthaler of Baltimore devised his plan for casting a whole line of type that any invention of this kind proved successful. The Linotype composing machine is such a miracle of human ingenuity as to be very difficult to describe. It must be seen at work to be appreciated. To look at, it is a solid, compact machine weighing about a ton. At the top are magazines to hold the type. This is not ordinary type, but a series of brass moulds or matrices from which the type is cast. Below is a keyboard resembling that of a typewriter, but with a larger number of keys, ninety in all.


THE LINOTYPE COMPOSING MACHINE

As the operator taps a key the machine takes a brass die from its place and sets it in the line; and as each word is completed, a 'space' is placed against the last die so as to separate it from the next word. The line being complete, a bell rings, just as in the typewriter, and the whole line is automatically pushed away to a place against a little pot of molten metal kept always at the proper

heat by the flame of a Bunsen burner. The machine then proceeds to pour out a sufficient amount of the type-metal on to the line of brass dies. This hardens almost instantly, and the line of type slides out into a galley—a flat, oblong tray—which is all ready for it. So line after line is prepared, the speed being six times that at which the most expert worker can set type by hand.

The most marvellous part of the Linotype machine is the mechanism which restores the used dies each to its proper magazine in the upper part of the machine, and does it with a certainty which no human brain or hand could ever hope to equal.

THE MONOTYPE KEYBOARD

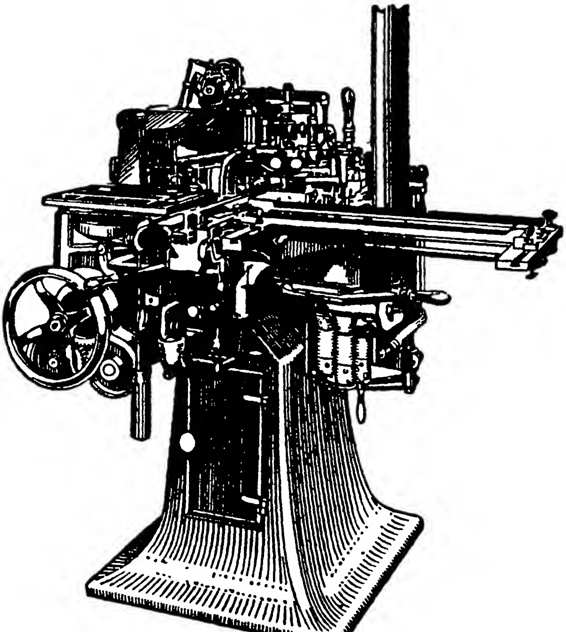
Although the Linotype machine was used originally for newspaper work its field of action now extends to book printing and general commercial work.

Even more amazing and intricate is the Monotype, with its two hundred and twenty-five keys to provide the characters and spaces. There is a machine for composing the matter, and this is worked by an operator who perforates a paper strip from a keyboard much like that of the typewriter. The strip is transferred to the casting machine, which it automatically controls, and the types are cast, not in whole lines, but in single letters. Types of many varied 'founts,' or patterns, are produced by the machine. The Monotype is what may be called a 'fool-proof' machine, for, should the compositor make a mistake so that the line is too long or too short, an

automatic device comes into play which slips the driving belt from the fixed to a loose pulley and stops the whole machinery.

The Monotype is generally preferred for composing and casting types used in printing books, and the Linotype machine is more largely used in newspaper production.

In both machines one of the most important features is that used types are melted down for service again and again. This saves the very considerable time needed for distributing hand-set types—that is, sorting them out, letter by letter, for return to their respective cases.



THE MONOTYPE MACHINE FOR CASTING TYPE

Another beneficial result of the use of typesetting machines is the healthier conditions which it provides. The friction of the hand types in the cases, combined with the natural oxidization that is always taking place, causes a poisonous dust to accumulate, which is injurious to the compositor. Lead poisoning is the result of this dust being taken into the system. Mechanical composition has changed this, for there is no lead dust on machine-composed type, and there is an absence of oxidization on account of the oil absorbed on the type

surface during casting. Operating the keyboard is a clean, pleasant, and interesting occupation compared with picking types from a case. At the caster there is no possibility of danger to health, as there are practically no fumes arising from the molten lead at the temperature at which it is used.

CHAPTER XVI

THE TELEPHONE

Speaking by Wire—How Alexander Graham Bell made the First Telephone —The Fight with the Western Union—Telephoning across a Continent.

IN early days inventions were often stumbled upon more or less by accident, but with the coming of the 19th century inventing became a business. I will not say that chance does not still at times aid the inventor; but with regard to big inventions which have been derived from the study of electricity, for example, chance has played a very small part, and in almost every case the result has been one definitely striven for and achieved by sheer patience and hard work.

Many years ago it became known that sound was due to vibrations of the air, and soon after telephony became an accomplished fact inventors began to wonder whether air vibrations and sound could not be conveyed along wires by means of electricity. Sixty years ago a German schoolmaster named Reis first attacked the problem, using a membrane made of collodion upon which the waves of sound produced by a musical instrument were made to strike.

Reis was a poor man, and his apparatus was made of just such things as he could lay hands upon. The sound receptacle was a large wooden barrel-bung which he hollowed out; the first membrane was nothing but the tightly stretched skin of a German sausage. A knitting-needle furnished the bar for the receiver, and this was fastened to the bridge of an old violin, which acted as sounding-board.

Reis did actually transmit musical notes with this first telephone, but was not successful in transmitting speech.

A little later an American, Elisha Gray of Chicago, applied himself to similar experiments. Gray had gone through college, working meantime as a carpenter in order to keep himself and pay his fees. After leaving college he began the study of electricity, and during his life put more than half a hundred patents to his credit. In his telephone he was the first to use variations of a steady current and to make his current act on a distant electro-magnet.

Unknown to Gray, another man was at work on the same problem at the same time. This was Alexander Graham Bell, who is regarded as the actual inventor of the modern telephone; and by a strange and remarkable coincidence Gray and Bell each filed their application for a telephone patent on the same day, February 14, 1876.

Alexander Bell was at that time a young man of twenty-nine years. He had been born in Edinburgh, but educated principally in London. Seldom if ever has an inventor been better trained for his special line of investigation, for Bell's grandfather, his father, one uncle, and two brothers were all teachers of elocution at various universities, and Alexander himself had been so carefully trained along the same lines that, when only sixteen, he obtained a post as teacher of elocution in a school. He was about twenty-one when he had the good fortune to meet two men who deeply influenced his future. One was Sir Charles Wheatstone of telegraph fame; the other, Alexander J. Ellis, who was an expert on sound and who showed Bell how tuning-forks could be kept vibrating by the power of an electric magnet, and how the tones of several tuning-forks could be blended so as to give a sort of imitation of the human voice. Bell at once began to wonder whether it would be possible to construct a sort of musical telegraph sending different musical notes over a wire by electricity.

There was consumption in the Bell family. Two of

Alexander's brothers died of this fell disease, and his doctor told him that he had better find a change of climate, so he went to Canada and there took up the work of teaching deaf-mutes to speak. He did so well that an offer came from Boston asking him to teach a school of deaf-mutes in that city, and there his success was so great that he was able to open a school of his own, which gave him a living. A certain Mr Thomas Sanders, whose only child was a deaf-mute, engaged Bell to teach his boy. Sanders was something of a scientist, and allowed the young teacher to use a cellar in his house as a workshop, and in this underground room Bell set to work on the musical telegraph which had for so long been his great ambition. Only now he meant to do more than send musical notes along the wire, for he was already convinced that it would be possible to transmit the human voice.

His studies had taught Bell that he could make sounds picture themselves upon smoked glass; and from this he went on to study the way in which sounds are received by the human ear, and learned how sound-waves, striking the delicate ear-drums, are conveyed through the thicker bones behind the drum. He set himself to make a pair of artificial ear-drums out of thin sheets of metal, and connected these by electrified wire. Working on these lines he eventually constructed his telephone.

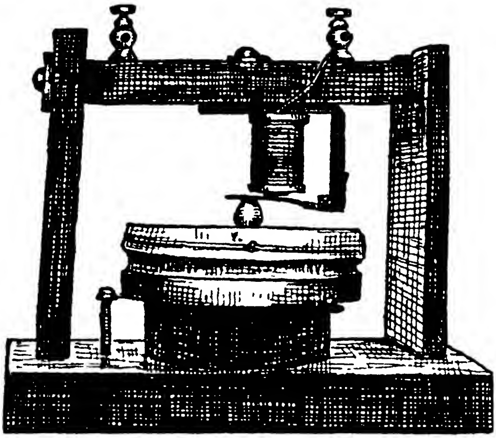
Like many other inventors, Bell spent so much time experimenting that his other work suffered, and he found himself with only two pupils and hardly any money. By this time he was married, and the outlook became so serious that it seemed to him that he must abandon his scientific investigations and devote himself to an attempt to earn a living. Not knowing what to do, and feeling almost in despair, he called on Professor Joseph Henry, at that time the greatest electrical expert in America, and, having told him what he had done so far,

asked the Professor's opinion as to whether it was worth while going on. " Certainly you must go on," declared the Professor.

" But I have not the necessary electrical knowledge," said Bell.

" You can get it," was the answer. " Indeed, you must get it, for you are on the track of a great invention."

Bell, tremendously cheered, went home and set himself to work night and day to obtain the needful knowledge of electricity. Some friends helped him with money, and he rented a workshop from a man called Charles Williams, and hired an assistant, a lad named Thomas Watson, who helped him to construct the two vibrating discs which he had in mind. These discs were connected by wire which stretched from the workshop into another room.



BELL'S FIRST TELEPHONE

On the afternoon of June 2, 1875, Bell was stooping over the disc at one end of the wire when all of a sudden a sound came clearly to his ears. He dashed into the other room. " Snap that reed again, Watson ! " he cried, and darted back. Next minute he caught the sound as before, and again he ran back, his face glowing with excitement. " Don't change anything," he ordered. " Let me see first what you did." Watson explained that the make-and-break points of the transmitter spring had become welded together, and all he had done was to snap this spring. The spring, of course, was magnetized, and

by its vibration over the pole of its magnet had sent the vibration across the wire just at the moment when Bell fortunately happened to be listening.

This was the beginning; but there were months of hard work before, in March 1876, the new instrument actually talked. Watson, who was in the basement, heard the disc say, "Watson, come here: I want you"; and, as Watson said afterward, he never went up three flights of stairs so quickly in all his life as he did in answer to the first telephone call. "I can hear you," he shouted as he burst into the room. "I can hear the words."

1876 was the year of the Centennial Exhibition held in Philadelphia, and Bell and his backers decided that this was the great opportunity for making the new discovery known to the world at large. One of Bell's backers, Mr Hubbard, was a commissioner, and he obtained leave to have Bell's telephone exhibited in the department of Education. Bell himself was by this time almost penniless. He had not even money to buy a ticket to go to Philadelphia, so remained in Boston, trying to find new deaf-mute pupils. The Exhibition had been open for six weeks, and not a word had been said about the telephone. Apparently no one had even noticed it. At last, in sheer despair, poor Bell got on a train, and, though he had no ticket, managed to reach Philadelphia. His friend, Mr Hubbard, told him that he had arranged for the judges to examine the telephone on the following afternoon, and Bell waited in trembling anxiety.

The day turned out very hot, and the judges were not inclined for violent exertion. When the time came for them to examine the telephone they were still in another department. It was seven o'clock when at last Bell saw them come in. One picked up the telephone receiver, looked at it, then laid it down again. Bell saw that all the judges were tired out and hungry and anxious to get away as soon as possible. His heart went to his boots.

At that moment a slim, elderly man came up. He had a dark skin and white hair, and was followed by several attendants. He came up to Bell with outstretched hand. "Professor Bell, I am very pleased to see you again," he said, speaking good English, but with a slight foreign accent. Bell almost collapsed, but managed to pull himself together. He bowed deeply. "Your Majesty is most kind to remember me," he said. For the newcomer was actually the Emperor Dom Pedro of Brazil, who some years before had visited Bell's school for deaf-mutes in Boston.

"And what is this invention of yours?" questioned the visitor. While Bell explained, a considerable crowd gathered. Never did an inventor have a better chance for making known his invention, and Bell, with his finely trained voice, made the most of it. The Emperor was intensely interested. "I must try it," he said; and while Bell went to the transmitter the Emperor put the receiver to his ear. A moment's pause—then the Emperor flung up his head. "*Dios!*" he cried. "It talks!"

Who should then appear but the aged Professor Joseph Henry, the same who had encouraged Bell in Boston. He, too, tried the telephone, and was equally astonished. So did many others. Until closing-time the room was packed, and next day the telephone was the greatest attraction in the whole Exhibition. It was moved to a central spot, and the judges gave it their certificate. In a week Bell was one of the best-known men in America, for every newspaper had columns of description of this marvellous new invention.

Perhaps the greatest piece of good-fortune, so far as Bell was concerned, was that he had such a friend as Mr Hubbard. Bell himself was a man of science rather than of business, and, left alone, would never have been able to make the most of his invention. But Mr Hubbard attended to the business side of the undertaking, and

under his care the telephone 'caught on' rapidly. By August 1877 there were nearly eight hundred telephones in use in America, and a Company was formed called 'The Bell Telephone Association.' The Company offered the invention to the Western Union Telegraph Company, but President Orton rather scornfully refused the offer.

"DIOS! IT TALKS!"

Mr Hubbard was not dismayed, but continued his endeavours, and presently the Western Union Company was dismayed to find that a good many people were using the telephone instead of the telegraph. They called Mr Edison to their aid, and started 'The American-Speaking Telephone Company,' advertising that they had "the only original telephone."

On the face of it, the odds seemed in favour of the great and wealthy Company, with its huge resources and clever inventors. But at this juncture Bell and Hubbard

were joined by a young man named Theodore Vail, who was one of the most brilliant business men of the day. He started to create a national telephone system, and fought the Western Union Company tooth and nail. For a time he held them ; then that marvellous genius, Edison, invented a new transmitter which was so great an improvement that it made the Bell telephone almost obsolete.

Things looked black indeed for the Bell Company. Bell himself had visited England, where Sir William Thomson had been greatly interested, and had shown the new invention to the British Association, but from a business point of view he had done nothing. He was ill, too, and on his return was forced to go to hospital, whence from his bed he wrote telling the Company that he had not yet recovered a penny for his invention, but, on the contrary, was seriously out of pocket by his researches.

At this critical moment a young man named Francis Blake showed Mr Vail a new transmitter equal to Edison's, and offered to sell it for stock in the Company. His offer was accepted, a new Company was formed, and the war was recommenced in earnest. The Western Union Company was fighting on the plea that the patent of Elisha Gray, which it had bought, was taken out before that of Bell. But it was at last proved beyond shadow of doubt that Gray's application was merely a declaration that he believed that he could invent a certain device, whereas Bell's was a statement that he had already perfected his invention. The battle in the law-courts lasted a year before victory fell to the Bell Company.

The result of the verdict was that shares in the Bell Company jumped to ten times their face value, and Bell, Watson, and the rest were able to sell out and retire with comfortable fortunes.

By 1880 the Bell Company possessed no fewer than

56,000 telephones, and by 1882 the number was doubled and the gross earnings were more than a million dollars (£200,000). It was in this year that Alexander received from the Government of France the Volta prize of fifty thousand francs and the Cross of the Legion of Honour. Once the telephone 'caught on' in America its progress was almost miraculous, and it is said that the Bell patent has proved to be the most valuable ever taken out.

In the British Isles, however, the progress of the telephone was much slower. Although Sir William Thomson and Mr Preece fully appreciated Bell's invention and did their best to make their countrymen realize its importance, English people were much less ready to take up the new means of communication. A Company was formed, called the United Telephone Company, which acquired the patent rights of Bell's electro-magnetic receiving telephone and the carbon transmitter invented by Mr Edison. In London and other great cities exchanges and call offices were opened, but so late as 1889 the English Company had in all only five thousand subscribers. Even to-day America uses more than five times the number of telephones per thousand of the population than England. In 1880 Mr Justice Stephen had decided that the telephone was a form of telegraphy, and was therefore under the jurisdiction of the Post Office; but the Company was allowed to carry on under licence from the Postmaster-General on payment of one-tenth of its receipts. By 1891 this tenth amounted to £40,000 and by 1898 to £100,000. The licence expired in 1911, and since that date the telephone system of Great Britain has been, like telegraphy, a monopoly of the Post Office.

The first London to Paris line was opened in 1891, but it was not until 1903 that a submarine telephone line was laid from Dover to Ostend. This line, sixty miles in length, was the longest which so far had been laid under

the sea. At that date, however, London could talk to Manchester, a distance of 200 miles, while New York was in communication with Chicago, the two places being 950 miles apart.

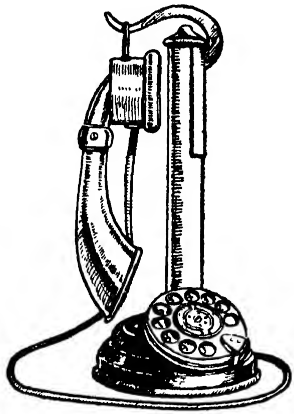
Telephone development in America during the present century has been amazingly rapid. It was Colonel Carty, Vice-President of the American Telephone and Telegraph Company, who first put the maze of overhead wires into underground conduits. This example has been followed to some extent in England, and to-day no storm can interfere with telephonic communication between the great cities, although in country districts the wires are still nearly all overhead.

Early in 1915 the transcontinental telephone between New York and San Francisco was opened. Nearly three thousand tons of copper wire cross 3400 miles of country, suspended upon 130,000 poles. Submarine telephones connect the West Indies with the mainland, and in 1921 Colonel Carty spoke from Havana in Cuba to Catalina Island, the famous fishing resort off the Californian Coast. The distance was no less than 5500 miles, yet the voices were heard with perfect clearness.

In spite of the competition of wireless telephony, the telephone system of the world is constantly spreading, and it promises eventually to enmesh every country with a network of wires. The telephone itself is almost a perfect instrument, and modern development is not directed toward improving the instruments used, but rather toward saving time in its working. This is effected by the automatic system. The automatic telephone has been described as the nearest approach to a human brain possible to machinery. One telephone is able to reach out to as many as a million different centres, all automatically controlled from the caller's instrument.

Under the old system the average time taken to complete a connexion was found to be forty seconds. With

automatic apparatus the corresponding time is only fifteen seconds; thus a saving of twenty-five seconds is effected upon each of the eight million calls made in London in a week.



AN AUTOMATIC TELEPHONE

Another immense advantage which the automatic possesses over the older system is that wrong numbers are called only when the caller himself makes a mistake. As soon as he has completed the necessary calling operation on his own instrument he can hear in his own receiver the bell ringing on the instrument he has called, or, if the line is engaged, a buzzing sound. More wonderful than all, his own instrument records the exact number of calls made with it.

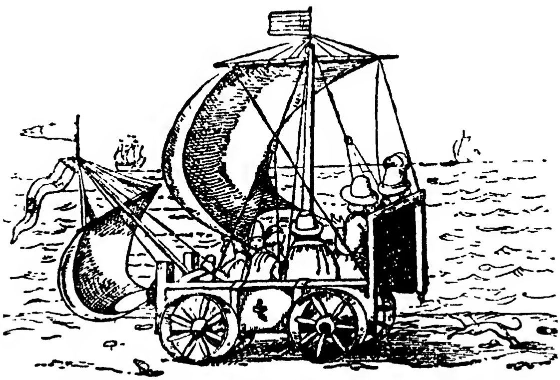
London is not the first great city to adopt the automatic telephone, and the change-over from the older system will not be completed there until 1940. By that time it is computed that London subscribers will have increased to at least a million.

CHAPTER XVII

THE DEVELOPMENT OF THE MOTOR CAR

Speeds of Early Steam Cars—English Enterprise destroyed by Stupid Legislation—Daimler's Invention—The Great Road Races—How the Pneumatic Tyre came into Being.

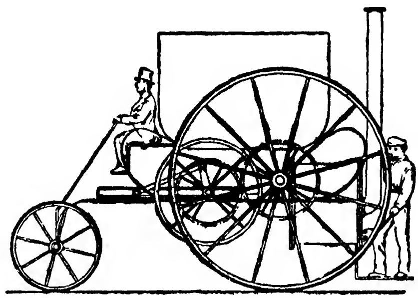
THE first vehicle to run by its own power upon a highroad was French. This was the steam carriage made by Cugnot in 1769. It was an amazingly clumsy contrivance, with a huge, kettle-like boiler, and its highest speed was about four miles an hour. It ended by running into a wall and upsetting, spilling hot embers and boiling water in every direction. Its unfortunate inventor was arrested and put in prison.



A WIND-PROPELLED CARRIAGE, 16TH CENTURY
A forerunner of the modern motor car.

Next came the attempts of various Englishmen, Murdoch, Watt, and Symington, until in 1802 Trevithick, assisted by Vivian, built a steam carriage which actually travelled at nine miles an hour. It was the disgraceful state of English roads which prevented Trevithick's steam coach from becoming a practical success; but a little later, when roads began to improve, all sorts of people built steam automobiles.

Between 1833 and 1836 Hancock's steam omnibuses ran in London and from London to Brighton at speeds up to twelve miles an hour, while Scott Russell's steam coaches made regular journeys between Glasgow and Paisley. Horse-owners, however, and railway companies, were intensely jealous of this new means of transport, and finally succeeded in inducing Parliament to pass the 'Red-flag Act,' which limited the speed of self-propelled vehicles to four miles an hour and which laid down that in front of each must walk a man with a red flag. This unfortunate piece of legislation, which was not repealed until 1896, deprived England of the honour which would otherwise have been hers of being the first nation to supersede the slow and uncertain method of horse traction by motor-driven vehicles.

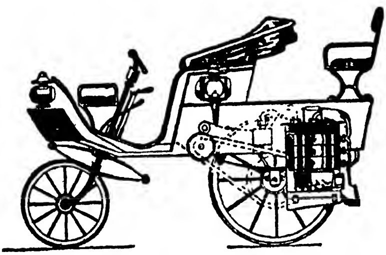


TREVITHICK'S STEAM CARRIAGE

The early steam vehicles have been so completely forgotten that very few beyond those who have specially studied records of the time have the least idea of their speed and power. Gurney's steam coaches climbed the steepest hills without trouble and at a pace much faster than that of any horse-drawn coach; while in 1830 a vehicle built by Messrs Ogle & Summers, and fitted with a tubular boiler, actually attained a speed of thirty-five miles an hour on the level and climbed a hill at twenty-four miles. It ran eight hundred miles without a breakdown. The steam coaches of the early thirties were immensely popular and always crowded; and since Hancock's London services ran over four thousand miles without serious accident, it could not be alleged that they were in any way dangerous. But those responsible for that iniquitous Red-flag Act were blinded by their

own foolish prejudices, and the law which they passed cost England countless millions and set back the clock of locomotion by many years.

For forty years so little was heard of self-propelled vehicles that hardly any memory of them remained. Then French inventors began to turn their thoughts toward road locomotion, and in 1873 M. Bollée of Mans built a steam car which ran from Mans to Paris. Five years later another car of this inventor's design journeyed from Paris to Vienna at the good round speed of eighteen miles an hour. In 1884 M. Bouton and the Comte de Dion brought out a motor tricycle, and a year later M. Serpollet built another vehicle fitted with a novel and ingenious form of boiler. But all these were steam carriages; and although steam will drive a car as fast as petrol, the steam car requires much more expert management than the petrol motor.



SERPOLLET'S STEAM CARRIAGE

Then at last came the great invention for which the world had been waiting, the petrol gas-motor, first made by Gottlieb Daimler, who, on March 4, 1887, ran for the first time a car propelled by an internal combustion engine. I do not think that there is any need to explain here the principle of the petrol motor, for it is even better and more widely known than the mechanism of the steam-engine. Petrol-driven cars soon appeared in numbers on the Continent, more especially in Germany and France; and in 1894 M. Pierre Giffard, editor of a great Paris newspaper, organized a motor race from Paris to Rouen, offering handsome prizes. There were ten starters, and the race was won by the de Dion car, which 'scorched' along at the tremendous pace of just over twelve miles an hour. Another race was organized

from Paris to Bordeaux and back, and this was won by M. Levassor on a Panhard car of four horse-power.

One point which these early cars proved was that the petrol carriage was at least as reliable as the steam, and that, too, in spite of the fact that in those days there was no variable gearing for hill-climbing, while electric ignition was still an invention of the future. The charges of gas were fired by an incandescent platinum tube. It was not until the Benz car arrived that electric ignition was first seen.

The Paris-Bordeaux race of 1895 caused an enormous sensation, and led to the Comte de Dion founding the Automobile Club of France. Car-makers were deluged with orders, and people who could not afford cars bought the motor tricycles made by the de Dion Company. It is most interesting to look back at the speed records made in the early races and see how rapidly they increased. From twelve miles in 1894 the pace rose in 1895 to fifteen. By 1898 cars were doing twenty-three miles an hour, and in the next year thirty.

In the Gordon-Bennett race of 1900 the average speed of the winning car over a course of 353 miles was 38½ miles an hour; by 1903 this had risen to 49¼. So speed went up by leaps and bounds until in 1905 the winner of the Brescia Circuit travelled the 311 miles at a rate of no less than 64¾ miles an hour.

Nowadays we try out motor cars on made tracks, and almost the only competitions held upon the open road are for testing the hill-climbing powers of motor cars. But at that date, less than twenty years ago, every country which had decent roads was constantly organizing motor-car races, and the great drivers such as Rolls, Edge, Farman, Fournier, Charron, de Knyff, and Girardot were popular heroes whose pictures were in every paper and magazine. Perhaps the greatest race of the kind ever held was that between Paris and Berlin in June 1901. In this the cars of all nations competed in a speed

championship, and the road was guarded by thousands of police and troops and officials. This race was won by Fournier in a Mors car, he having covered the 740 miles in just under seventeen hours actual travelling. His average was 44 miles an hour, though at times he had been travelling at very nearly 80 miles an hour.

America's first road race for motor carriages was held on April 14, 1900, on the Marrick road, in Long Island. There were nine competitors, five being petrol-driven, three steam, and one electric. The prize was won by A. L. Riker with an electric motor car; he covered the course at twenty-five miles an hour. It is interesting to note that in those days, a quarter of a century ago, electric cars were built in considerable numbers, and their designers were confident that they would supersede petrol-driven vehicles. But, owing to the great weight of the necessary accumulators, the electric car, although delightfully silent, simple, and clean, has so far not succeeded in competing with the gas-driven vehicle.

The growing success of the motor car on the Continent roused emulation in England, and pressure brought to bear on Parliament caused the repeal of the ridiculous Red-flag Act and the passing of a new law which permitted autocars to travel at a speed of twelve miles an hour. In order to celebrate the removal of the old restrictions, a procession of motor vehicles was organized from London to Brighton. 'Freaks' is the only term one could apply to the majority of the cars which took part in that test; and, so far as I can remember, less than half of those that started reached their destination. English-built vehicles were particularly untrustworthy; but this is hardly surprising, seeing what a long start the Continental designers had obtained. English drivers, however, were soon to the fore, and it was not very long after the London-Brighton race that the Hon. C. S. Rolls, driving a Panhard on a private road, covered the course at a rate of nearly forty miles an hour.

Within less than ten years English builders had made up all their leeway, and by 1902 were producing cars the equals, if not the superiors, of anything built elsewhere. In that year Mr S. F. Edge, driving an English-built Napier car, won the Gordon-Bennett race against all comers.

But if the success of the motor car was great in Europe, what shall we say of its progress in America? According to statistics, the world at large possessed in 1925 just under sixteen millions of motor vehicles. Of these Great Britain owned 469,490, Canada 554,874, and the United States nearly thirteen and a half millions! From Oregon's mountains to Florida's sandy plains, the whole of the United States throbs with motor-propelled vehicles of every possible description.

The change which motors have made in the United States is almost miraculous. At the beginning of the present century there was hardly a road worthy of the name in the half-continent. Even within a few miles of the great cities the highways were shockingly bad and in most cases quite unfit for heavy traffic. To-day hundreds of thousands of miles of fine roads have been constructed. Every new experiment in road-building has been tried, and you can drive a car in comfort from New York to San Francisco or from Seattle in the extreme North-West to Tampa in the far South.

For mass-production of cheap, yet sound, cars the world owes a great debt to Henry Ford. Ford devoted his attention to horseless carriages as early as 1879. He followed all the modern developments, and eventually came to the conclusion that manufacturers "were in such a hurry to obtain something to sell that they did not take time for adequate preparation." In 1903 he formed the Ford Company. Its success may be gathered by the fact that, when in 1919 Mr Ford's son Edsel bought up the outstanding shares, he had to pay 12,500 dollars for each, the original price having been one hundred dollars

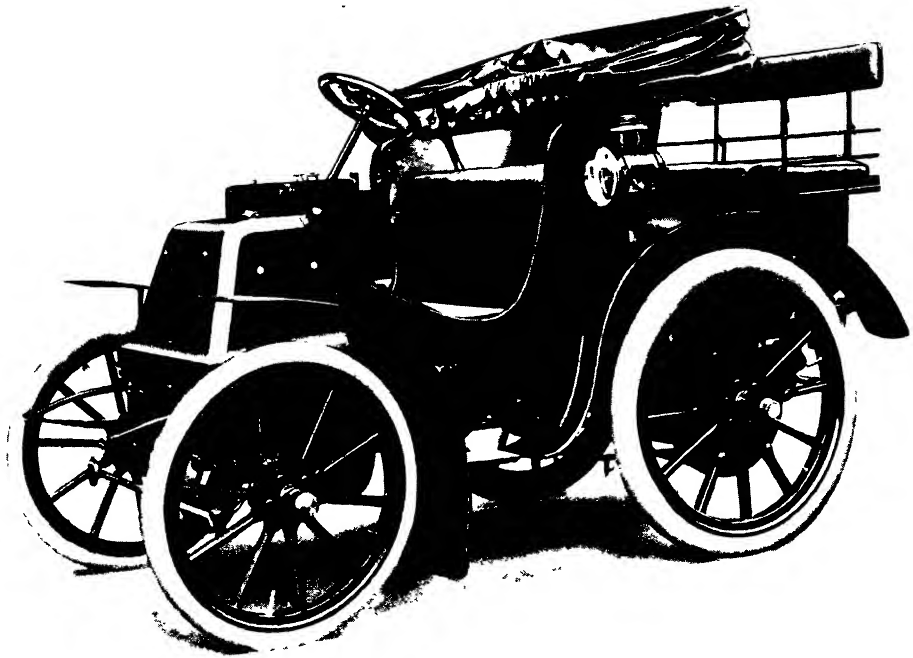
only. It was in 1909 that Mr Ford, after many experiments, standardized his 'Model T.' From that time onward he has built his chassis on one model only, so that all parts are interchangeable. He also decided to paint all his cars black. At the time he made the following announcement:

"I will build a motor car for the great multitude. It will be large enough for the family, but small enough for the individual to run and care for. It will be constructed of the best materials, by the best men to be hired, after the simplest designs that modern engineering can devise; but it will be so low in price that no man making a good salary will be unable to own one, and enjoy with his family the blessing of hours of pleasure in God's great open spaces."

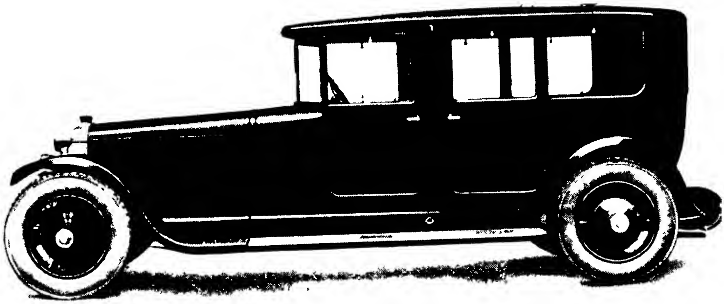
In 1911 one of these 'Model T' cars was driven to the top of Ben Nevis (4406 ft.), and in that year more than fourteen thousand Ford cars were sold in England.

The principle of the motor-car engine is still the same as that invented by Gottlieb Daimler, but the improvements have been such as to convert an uncertain plaything into a machine so reliable that it will run for thousands of miles with no attention except the provision of oil, petrol, and water. The first great improvement was the substitution of a magneto for the dry-cell batteries and transformer coil which formerly provided the ignition; the second was the alteration from the old makeshift drip-feed arrangement to the modern carburettor. In the old machines it was simply 'a toss-up' whether the gas was mixed in proper proportion with air, but nowadays automatic devices regulate the mixture to perfection and procure smooth running and great economy of fuel. The oiling system has also been revolutionized, and with the modern car all that is necessary is to keep the oil container filled to the proper level. The oiling of every part of the engine is then automatic.

The great advance in the power, efficiency, and comfort



LUXURY IN 1900—A 6-HORSE-POWER DAIMLER MADE FOR KING EDWARD VII



TWENTY-FIVE YEARS LATER—THE DAIMLER LANDAULETTE
WITH ITS INTERIOR FURNISHINGS

of the motor car achieved within a period of less than forty years is revealed at a glance by a comparison of the six horse-power Daimler made for King Edward VII in 1900, three years after the appearance of Daimler's first car, with the Company's present-day enclosed landaulette, with its powerful engine, its ample accommodation, and its sumptuous furnishings.

No wheeled vehicle could travel at the speed of the modern motor car without some means for eliminating road shocks and vibration. This is provided for by the pneumatic tyre, the invention of the late J. B. Dunlop. In November 1909 a great banquet at the Hotel Cecil in London was held to celebrate the coming of age of the pneumatic tyre. Five hundred business men gathered from all parts of the world, and sitting on the right hand of the chairman, Prince Francis of Teck, was a grey-bearded man of nearly seventy, Mr Dunlop himself.

"I tried two of the first pneumatic tyres I ever made on my son's tricycle," he said. "I fitted them on to the back driving-wheels. The forks of the machine were too narrow, I remember, for me to attach one to the front wheel. Clumsy things they were, as you may imagine, yet they enabled my boy to win a race against a number of other boys. More than once I had been mindful to give the whole thing up. It was so tedious. I had to buy rubber, and fashion it to my purpose with my own hands. The very first pneumatic tyre I made I fitted to a heavy block of wood, and ran it to and fro across my own backyard in order to test it."

It was in July 1888 that Mr Dunlop patented his pneumatic tyre, and at that time there were but 300,000 cycles in the world. Twenty years later there were more than three million, to say nothing of some hundreds of thousands of motor cars. And this great extension of road locomotion could never have come about but for what was first described as 'an inflated rubber band.'

CHAPTER XVIII

ELECTRIC LIGHT AND THE PHONOGRAPH

Our Debt to Mr Edison—A Miracle of Patience—The Difference between Discovery and Invention—The Making of the First Phonograph.

THERE is an advertisement which runs : " When you see a pillar-box think of so-and-so's pen." In similar fashion one might be tempted to write : " When you see an electric lamp think of Edison."

Yet Edison was not the inventor of the electric light, for lights produced by electricity were made more than a quarter of a century before that great man was born. It was Sir Humphry Davy himself who, in the year 1810, first formed an electric arc and produced a real electric light. More than one electric lamp was patented during the first half of the 19th century; and in 1858, when Edison was only eleven years old, an electric lamp designed by Dubosc was used in the South Foreland Lighthouse in Kent.

You are then quite entitled to ask why it is that Edison's name is always coupled with that of the electric light. In this chapter I will do my best to make the matter clear.

The electric light invented by Sir Humphry Davy was the arc lamp. Now the arc lamp consists of two carbon rods to which the terminals of a powerful battery are connected. The free points of the rods are separated by a short gap across which the current passes, forming a brilliantly luminous electric arc. Such a light is immensely powerful, and suitable only for illuminating big spaces. It has various disadvantages, for at times it crackles and spits, while small portions of burned carbon

drop from it. The arc light was too bright and too big for indoor use. What was wanted was little lights and a way of distributing the current to private houses just like gas. That was the problem to which Edison set himself.

Before I explain how he solved it, I want to go back a little and tell you something about Edison himself. Just as he is by far the greatest of living inventors, so the story of his beginnings is most interesting, for it shows how a poor boy, with no advantages of birth or education, can rise to an eminence hardly to be dreamed of. Edison's father was Dutch, his mother Scotch, and he was born at Milan, Ohio, in 1847. His people were very poor; but his mother, who had been a teacher, gave him some schooling. He read everything he could lay hands upon, and at twelve became a newsboy on the Grand Trunk Line running into Detroit.

In America boys walk through the long railway cars, selling papers, books, and sweets. Edison made his living by selling papers, and spent his spare time in a little laboratory which he was allowed to fit up in one corner of a baggage car. Bottles and retorts he begged from the railway workshops. The editor of the *Detroit Free Press* gave him a quantity of old type, and with this he printed a paper of his own, and sold it on the trains. Often he got a piece of important news from a station-master, set it up at once, and sold it, so beating the newspapers which might be awaiting the passengers at the terminus. He called his paper *The Weekly Herald*, and one copy still survives, which Mrs Edison has preserved. One day, while working in his train laboratory, a phosphorus bottle upset and caused a small fire. The conductor not only stopped his experiments, but lifted the boy by the ears, thus setting up the deafness from which the great inventor has suffered ever since.

Edison's chief hobby was electricity, and his great

ambition was to become a telegraph operator. Some time after the phosphorus disaster he saved the life of the small son of the stationmaster at Port Clements. The boy was on the permanent way and almost under the wheels of a train when young Edison snatched him away. In return, the lad's father taught Edison telegraphy, and in due course he obtained the position he coveted at Fort Huron. Before very long he became extremely expert, and was able to take the messages more rapidly than any operator on the line. At last a man was put on as despatcher who was too rapid even for Edison. This led to Edison's first real invention. He got two old Morse registers, and arranged them so that the dots and dashes were recorded by the first instrument and developed by the other at the desired rate of speed. So if news came in at the rate of forty words a minute, the pace could be reduced to twenty-five.

Edison's next invention was an automatic repeater which could be attached to a line, and of its own accord would send a message onward. This device worked excellently; but, unluckily for Edison, the nephew of the manager was just completing a similar instrument, and the very unfair consequence was that Edison got the sack. He went to Boston, and there astonished his colleagues by the lightning speed at which he was able to receive. While in that city he took out his first patent for an electrical vote recorder, and went with his machine to Washington, where he showed it to the Chairman of Congress. The Chairman looked it over. "Young man," he said, "it works all right, and could not be improved upon. But it is the last thing we want here. Take it away."

"Then and there," says Edison, "I made up my mind that I would never again invent anything that was not wanted, and I believe that I have kept my vow."

In 1868 Edison gave up his position as telegraph opera-

tor, and determined to use his savings to become an inventor. He went to New York, and the very first day after his arrival walked down Wall Street, the financial centre of the United States. He was attracted to the office of the Law Gold Indicator, where one of the first ' tickers,' or stock exchange indicators, was at work. It had gone wrong, and half a dozen workmen were vainly trying to find out where the trouble lay. Edison watched a while, then said that he thought he could put it right. Mr Law rather scornfully told him to try. Edison merely moved a loose contact spring which had caught between two wheels, and the ' ticker ' at once began ticking again merrily. The workmen looked foolish, and Mr Law asked Edison to step into his private office. He came out five minutes later with the position of manager at three hundred dollars a month.

At once he began to improve the indicator, and his reward was a cheque for forty thousand dollars (£8000). Now at last the young inventor had the capital he required, and set himself to real invention. His first great feat was the invention of duplex or quadruplex telegraphy. By the latter device two messages can be sent simultaneously along the same wire in opposite directions. He made a great deal of money, and started his famous workshops and laboratories at Menlo Park. And so at last we come to his great work on electric lighting.

It was in 1878 that he first saw an arc lamp, and at once the idea was born of lighting houses with electric light and so superseding coal gas. The forming of a multiple arc with which incandescent lamps should be used was, to a mind like Edison's, comparatively simple, but to find a filament which would stand up without melting or short-circuiting was a very different matter. He tried platinum wire, but it melted. He tried an alloy of the rare metal iridium with platinum, but it would not stand. He tried silicon, boron, and a score of

other substances. Carbon he did not try at first, because he knew that it oxidized so readily. But at last he was driven to experiment with carbon, and after much difficulty and many failures succeeded, on October 21, 1878, in making a filament of cotton thread thoroughly carbonized. When this was tested it stood up to 275 ohms.

EDISON WATCHING THE LAMP

Edison watched it, every minute expecting to see it burn out, every minute more and more pleased that it continued to burn. You will have some idea of Edison's tremendous strength of mind and body when I tell you that he watched the lamp for forty-five hours without sleep and with very little food. Then at last the filament collapsed.

But now the inventor knew that he was on the right track. Carbon of some sort was what was needed for the perfect filament, and he set to work experimenting with every sort of carbon on which he could lay his hands.

The best result was obtained from a filament of bamboo broken from an old fan. Edison set to work to study bamboos, and learned that there were twelve hundred varieties of the plant. He tried six thousand specimens, and spent a hundred thousand dollars (£20,000) on research. At last he found three sorts, all South American varieties, which were what he wanted, and was ready to give his new light to the world.

He determined to have a central station, and spent days studying maps of New York in order to discover the best situation for it. He finally bought two old buildings in Pearl Street, and there he installed the first electric-lighting plant, not only in America, but on this planet.

There were, however, still rocks ahead. Edison determined to have a high-speed engine, so went to a famous builder and said that he required a one-hundred-and-fifty-horse-power engine that would run at seven hundred revolutions per minute. The builder said it was impossible. "It is not," said Edison; "but if you cannot make it, I will find some one else who can." He did; but when the engine was installed, it nearly shook the building down. Edison had to get new engines which ran at three hundred and fifty revolutions and gave one hundred and seventy-five horse-power. These worked well; and on September 4, 1882, all was at last ready. He turned on the current, and so perfectly had everything been prearranged that the light service continued, with only one short stoppage, for eight years.

Edison's success was so immense that all sorts of people tried to pirate his invention, and, like Morse and Bell, he had to fight desperately for his rights. Lawsuits went on for fourteen years; and when at last they were decided in his favour, his patent had but three years left to run. It may perhaps give you a further idea of the extraordinary thoroughness of Edison when I tell you that he has to his credit no fewer than one hundred

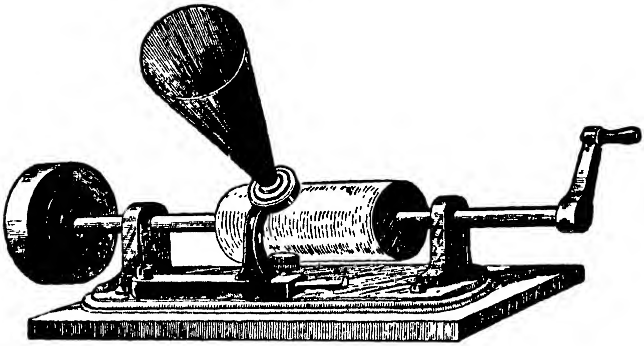
and sixty-nine different patents on electric light alone, ninety-seven on dynamos, twenty on electric meters, twenty on storage batteries. In all he has taken out nearly two thousand different patents.

Edison never allows himself to be beaten. He has the rare faculty of being able to concentrate his vast mental energies upon a single problem, to the exclusion of all else. In an argument during a lawsuit concerning one of Edison's patents counsel made a remark worth recording. Speaking to the judge, he said: "If your honour wished him to do so, Mr Edison could go into a field of grass a mile square and select therefrom the most perfect blade." The learned gentleman was not far wrong, for the real Edison is a man of tireless industry, who gains his results by intense effort intelligently applied. With him it is an unalterable rule never to allow any new device to issue from his laboratory until it is absolutely perfect. "Genius is one per cent. inspiration and ninety-nine per cent. perspiration," is a favourite saying of this great American. You might almost call it his motto, for certainly he has never spared either brain or body in the pursuit of knowledge and new inventions.

Edison always draws a very broad line between 'discovery' and 'invention.' In his idea, discovery is what he calls a 'scratch,' something that might be disclosed to anyone, and for which very little credit is due. Invention, on the other hand, is the result of that peculiar mental faculty which not only perceives a new phenomenon but is able to apply it to a new use.

Yet one of Edison's greatest achievements, the invention of the phonograph or talking-machine, was in part at least inspiration. In his early work with automatic telegraph instruments working at high speeds, Edison made some experiments with embossed strips which were moved rapidly beneath a stylo or metal pen so as to vibrate it. In vibrating, this stylus produced a peculiar

sound. Now an ordinary person might have heard this sound without attaching any particular importance to it. Not so Edison. At this time the inventor was working on telephones as well as telegraphs, and consequently was studying acoustics, or the science of sound. All in a flash it came to him that, if the undulations on the strips could be given popular form and arrangement, a diaphragm could be vibrated so as to reproduce any



THE FIRST PHONOGRAPH

desired sounds. In that moment the idea of a talking-machine was born in Edison's brain.

So much for the inspiration, but the problem before the inventor seemed a very stiff one. Whether what followed was also inspiration or whether it was the result of pure reasoning, I do not profess to know, but, at any rate, Edison's next step was the idea that these undulations might be produced by the sounds themselves. It remained to find a substance capable of receiving the sound waves, and for this I believe that Mr Edison used simply tin-foil. He made a rough sketch of his model, and handed it to one of his assistants, John Krusei, to construct.

The story is that Krusei stuck to it for thirty hours on end and finished it. Then, standing in his laboratory, with his assistants round him, Edison slowly turned

the handle and spoke into the receiver the first verse of " Mary had a little lamb." The cylinder was turned back to the starting-point, and there came, like an echo, the words which Edison had first spoken. Next day the inventor took the model down to the office of *The Scientific American*, and it is on record that no invention—not even Bell's first telephone—produced such a sensation as this first crude talking-machine. The patent for the phonograph was applied for on Christmas Eve, 1877, and the date is peculiarly appropriate, because I do not think that any other invention—not even wireless—has done more to add to human happiness than the gramophone.

Although Edison's very first phonograph was able to record and reproduce speech, its tone was harsh and the records were unsatisfactory. Edison, however, was too busy with other matters to perfect the invention, and this was done by Graham Bell and his brother together with a partner named Tainter. It was they who first made the disc records resembling those used to-day. Since their time, very many improvements have been made, so that the gramophone of to-day will reproduce almost any sound with extraordinary clearness and perfection.

It may be interesting to tell just how the flat disc records used in the modern gramophone are made. A metal sheet is coated with a very thin film of wax, from which the sharp steel point moved by the recording diaphragm removes small portions, thus baring the metal beneath the wax. The sheet is then covered by an acid which eats into the bared portions, but does not touch the parts still covered by the wax. When the acid has done its work, the wax is removed, and there is left a *negative* record made of metal. It is from this negative that the vulcanite *positives* are prepared for the market. The modern record is so perfectly made that it is almost unbreakable, and if proper care is taken can be used many hundreds of times without deteriorating.

CHAPTER XIX

BALLOONS AND AIRSHIPS

How Men Fly—The First Balloons—Vain Attempts to steer Balloons—The Story of the Dirigible—A Long Series of Disasters.

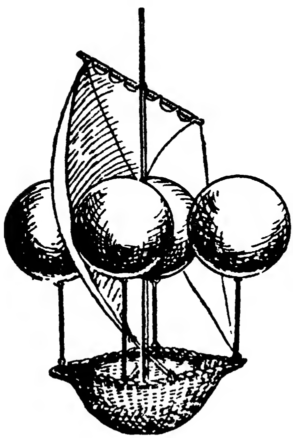
THAT to fly has always been one of man's greatest ambitions is proved by the fact that so many of the great mythical heroes were provided with wings or winged horses, and that in modern times countless people have spent time and money, and even their lives, in vain attempts to make flying-machines.

Perhaps you have heard that the Chinese claim that they were the first people to fly. We have this much evidence in favour of their claim, that a French missionary to China, writing in the year 1694, mentions that the people at Pekin sent up a balloon in celebration of a new Emperor. Unfortunately, we are not told what the balloon was made of or how it was inflated.

The first record of ballooning in Europe dates from the year 1709. A Brazilian named Bartolome Lorenzo di Guzmao, who was born at Santos in 1689, came home to Portugal in 1708, and, so it is stated, made trial of a balloon on August 8, 1709. His 'globe,' as it is called, rose from the courtyard of the building called the House of the Indies in Lisbon. It was caused to rise by the burning of a certain material to which the inventor applied fire. We are told that the King and Queen watched the ascent; but the account, unfortunately, gives no details of how the balloon was made or of the actual height to which it rose. Whether the story is true or not, I cannot guarantee; but the best proof that di Guzmao did do something very much out of the common is that he was prosecuted for being a wizard and had to fly the country.

Even before his time, in 1670, a Jesuit, Francis Lana, had proposed an airship which should be lifted by four hollow copper vacuum balls, each 25 feet in diameter. Lana was right, of course, in believing that these would be lighter than air. But he failed to realize that the atmospheric pressure on each ball would crush it quite flat before all the air had been exhausted from its interior.

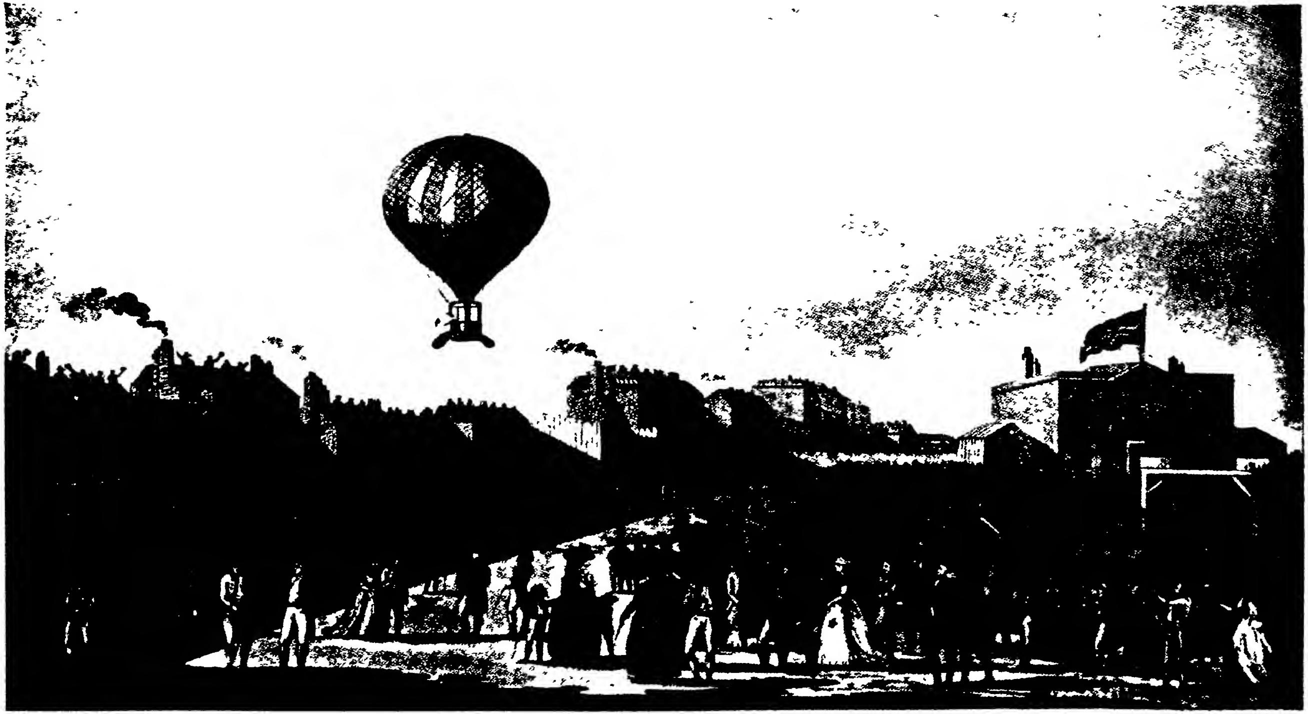
In 1766 the great British chemist Cavendish showed the scientific world that hydrogen gas was lighter than air, and Dr Black of Edinburgh made a little balloon of calf-gut and filled it with hydrogen. But the balloon proved too heavy to be lifted by the gas, and when others experimented with paper envelopes they found that this material would not hold the gas.



LANA'S AERONAUTICAL MACHINE

A little later the brothers Montgolfier began their experiments. It is an interesting coincidence that, just as the first heavier-than-air machine was invented by two brothers, the Wrights, so the first real balloon was the work of two brothers. Stephen and Joseph Montgolfier were the sons of Peter Montgolfier, a paper manufacturer of Annonay in France. They got the idea that if they could fill a paper bag with some cloud-like substance it would rise, so they made some huge paper bags under which they burned fires of chopped straw. To their great delight, up went the bags, but it was some time before they realized that it was not the smoke, but the hot air with which the bags were filled, that caused them to rise.

However, as soon as this knowledge dawned upon them the rest was comparatively simple, and after experiments with small balloons they made a big spherical paper



VINCENT LUNARDI THE FIRST AERIAL TRAVELLER IN ENGLAND—MAKING HIS ASCENT

From an aquatint after J. Brewer

[*See p.* 198]

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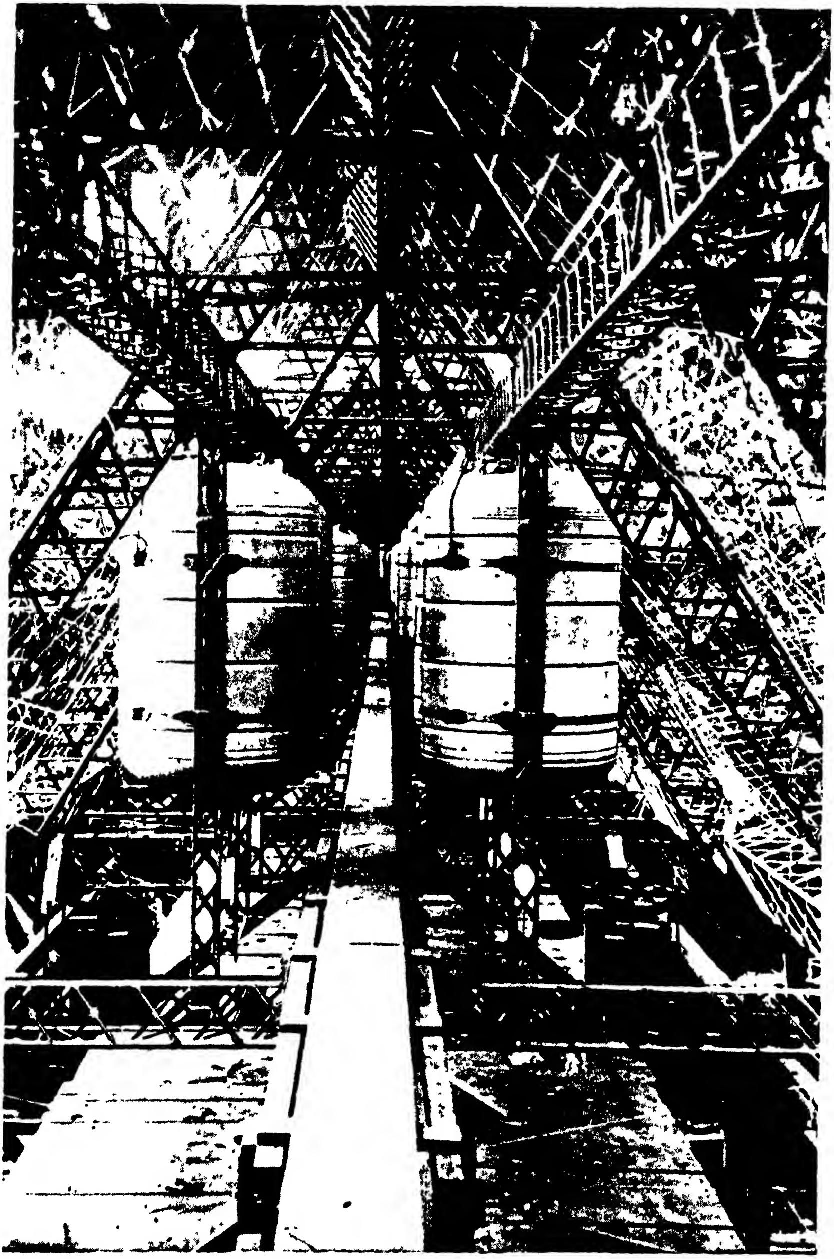


PETROL TANKS INSIDE CENTRE SECTIONS OF THE UNITED STATES NAVY AIRSHIP ZR-1

Photo Keystone View Co.

balloon 30 feet in diameter, which they sent up from Annonay on June 5, 1783. A great crowd watched it dwindling into the blue sky, and it rose to a height of about a mile and a half before it cooled enough to descend.

This balloon had no passengers, nor had the next, which went up in the following August. This was made of thin silk covered with the newly discovered caoutchouc, or indiarubber, and, though 13 feet in diameter, weighed only twenty pounds. It was filled not with hot air but with hydrogen, and its inventors were M. de Saint Fond, a well-known naturalist, M. Charles, and two brothers named Robert. The balloon was sent up from the Champs de Mars in Paris, and rose rapidly to 3000 feet, when it burst. The remains fell in a field fifteen miles away, and were destroyed by terrified peasants.

Meantime the Montgolfiers were busy building a much bigger balloon, and this had a car in which were placed a sheep, a cock, and a duck. The balloon itself was of linen covered with paper. It was sent up from Versailles on September 19, 1783, stayed in the air eight minutes, and came down quite gently. The sheep and the duck were unhurt, but the cock was in a bad way. The wise men decided that the poor bird was suffering from the effects of the thin air in the higher regions, but it was presently discovered that it had been trodden on by the sheep.

So far, no human being had trusted himself in the air, but a few weeks later a pilot was found, M. Pilâtre de Rozier, brave enough to trust himself aloft. The balloon in which he ascended was, however, a captive one, and did not rise to more than a hundred feet. On the following November 21 de Rozier and a friend, the Marquis d'Arlandes, made the first free balloon ascension from Paris, and, drifting for twenty minutes at a height of 500 feet, came safely down in a field five miles from the starting-point. The great Benjamin Franklin was among the spectators of this ascent, and when some one asked him

what he thought of this wonderful new means of travel, he smiled. "Of what use," he asked, "is a new-born babe?"

The first ascent in England of an aeronaut was made by Vincent Lunardi from the grounds of the Hon. Artillery Company in London on September 15, 1784, but James Sadler is usually regarded as the father of English aeronauts. His first ascent was made at Oxford a month later than Lunardi's, and during the next thirty years he made many others. He had various narrow escapes, one of which was when he endeavoured to cross the Irish Channel from Dublin. His balloon, with its highly

INTERNAL BALLONETS OF A ZEPPELIN

decorated car, was blown out to sea by a contrary wind, and the aeronaut was rescued from the water.

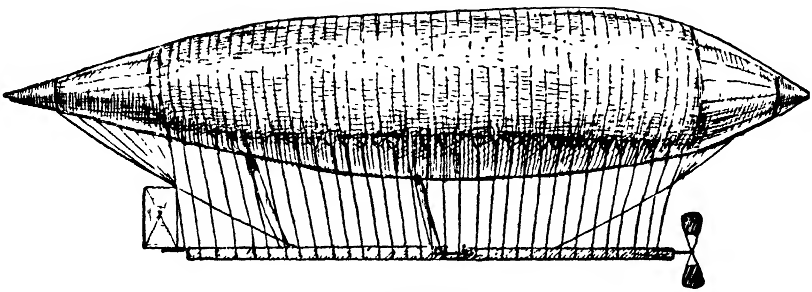
Benjamin Franklin was right; and until men learned, more than a century after its birth, to control the flight of a gas-bag, the balloon remained little more than a toy.

Meantime many experiments were made. In 1852 Giffard succeeded in making a small steam-engine of three horse-power which weighed only a hundred pounds, and this he attached to the car of a cigar-shaped balloon. The power was just enough to move the balloon in still air, but the experiments were so costly that he had to give them up. Later, Haenlein, a German, made a dirigible—that is, an airship lighter than air—on more modern lines, for he had the internal ballonet now always used in dirigibles. A small gas-engine drove a four-bladed propeller at forty revolutions a minute; but the balloon, filled only with coal gas, did not lift very well.

"La France," built by Captain Renard in 1884 and driven by an electric engine, was the first dirigible that

would steer at all. But it was slow and its range too limited to make it of any practical use.

After "La France," sixteen years elapsed before a young Brazilian, Santos-Dumont, began his historic experiments with dirigibles, and after several attempts succeeded in winning the Deutsch prize of three thousand pounds by travelling from St Cloud round the Eiffel Tower and back. This was on October 9, 1901. The distance was nine miles and the time taken thirty minutes. His airship was 108 feet long, 20 feet in diameter, and drawn



"LA FRANCE"

by a sixteen horse-power motor engine. Two years later the Lebaudy brothers built a larger dirigible with a speed of twenty-four miles an hour. After this, each year saw fresh dirigibles built in France, England, and Germany. Each year also saw fresh disasters in connexion with these lighter-than-air machines. The Wellman airship, built to conquer the North Pole, was destroyed by a gale. Of the Lebaudy ships, one was destroyed by a storm at Châlons, a town on the river Marne, another was torn from its moorings by a gale which hurled it across England and flung its shattered remains into the Atlantic. The first British air dirigible was destroyed by fire at its moorings, and the first Zeppelin also disappeared in flames. The dirigible invented by Severo burst into flames in mid-air, and the inventor and his mechanic fell from a fearful height.

Six of Count Zeppelin's great airships were destroyed

by accidents, and in 1913 a seventh, a huge craft nearly five hundred feet long, was wrecked in a gale.

But for the Great War the various Governments would probably have abandoned the apparently hopeless attempt to build dirigibles. But then, as we all know, Germany devoted immense sums to the building of large airships, and in 1915 succeeded in dropping bombs on London from such vessels. Zeppelins, however, gave way to aeroplanes of the large Gotha type as soon as it was shown that the former were practically defenceless against attack from above by the more nimble aeroplane.

England was driven to build 'blimps' and other types of lighter-than-air craft for the purpose of hunting submarines, and much progress was made. Since the War the Atlantic has been crossed by airships; yet, even so, the tale of disaster is not at an end. In August 1921 the world was shocked by news of the dreadful end of the giant R 38, which broke in two at a height of a thousand feet, caught fire, and fell blazing into the river Humber. She had a crew of no fewer than forty, of whom only four survived.

Up to the date of the Great War and for some time afterward, the only gases that could be used for inflating lighter-than-air machines were coal gas and hydrogen, both of which are highly inflammable and, when mixed with ordinary air, terribly explosive. When R 38 blew up, so fearful was the force of the explosion that glass was blown across the streets from the windows of warehouses on Hull quayside. The only gas that is both lighter than air and not inflammable is helium, and up to a recent date helium was only a curiosity of the laboratory. Now means have been found of making it in large quantities, but it is still extremely costly. Nevertheless, it seems to offer the best hope for the future of the dirigible, and to-day all the great Powers are busy with the construction of these monsters. The

plans are, of course, closely guarded, but it may be that new discoveries will result in a dirigible which will be both safe and manageable. If so, the triumph will be as great as any that man has ever won over the forces of nature, for never has any problem of invention been more difficult to solve, nor has any been the cause of more frequent and terrible disasters.

CHAPTER XX

THE AEROPLANE

Flying-machines Heavier than Air—The Flapping Machine—The Soaring or Gliding Machine—How Man has beaten the Birds—The Ever-increasing Uses of the Aeroplane.

FROM earliest times nothing was more familiar to man than the flight of birds, and all his earlier efforts to fly were attempts to copy birds. The 'ornithopter' was his first flying-machine. This was made with flapping wings, and we read of men making wings and trying to use them throughout the Middle Ages. But a bird's bones are hollow, and its weight extraordinarily small for its size, while its muscles are, comparatively speaking, enormously more powerful than those of a man, so it is not surprising that most of the earlier experimenters failed to rise from the ground, or, if they started from a height, broke themselves up.

In 1809 an Englishman named Degen constructed a machine with deeply concave wings which were covered with taffeta bands arranged like the feathers of a bird's wings. With these he is said to have risen to a height of fifty-four feet, but the fact is that his apparatus lifted only seventy out of the one hundred and sixty pounds of the weight of the operator and his machine, the other ninety pounds being balanced by a counter-weight attached to a rope passing over a pulley. So what Degen's invention really proved was man's inability to fly by means of his own muscles. Next came an ingenious flying-machine invented by a Frenchman named Trouvé. It was worked by a U-shaped Bourdon tube, the tendency of which is to flatten out when subjected to sudden in-

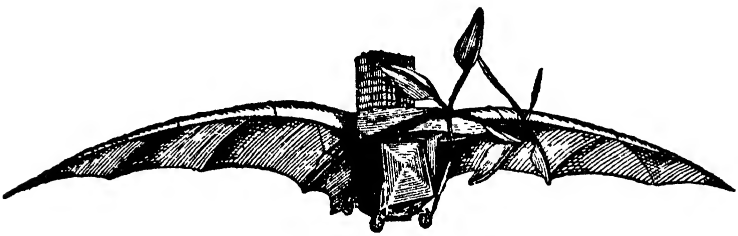
ternal pressure. This pressure Trouvé obtained by firing cartridges inside the tube. The machine (it was only a small model) did actually fly for a distance of nearly a hundred yards. The tube, flattening out at each explosion, worked a pair of wings which flapped like those of a bird.

In the early eighties of the last century, Hargrave, an Australian, began a series of experiments with box-kites, and went on to build little flying-machines driven successively by clockwork, rubber bands, compressed air, and steam. In the last of these machines the wings flapped at a speed of 342 strokes to the minute, and the total weight of the whole thing, including twenty-one ounces of fuel and water, was only seven pounds. The wings were thirty-six inches long and from four to nine inches wide. The lightness of Hargrave's power plant has never been surpassed except by the latest petrol engines, and his model flew for a distance of several hundred feet.

A number of experiments were also made during the 19th century with what are called 'helicopters'—that is, machines made to rise straight into the air by the drive of a wide-winged propeller. It is interesting to note that the wonderful Italian artist and inventor, Leonardo da Vinci, who was born in 1452, made a plan for a helicopter to be built of iron and bamboo framing, but dropped the idea because he had no power suitable for driving the screw. Several of the model helicopters made during the 19th century were capable of flight. In 1870 Penaud invented one driven by a rubber band, which had quite a run as a popular toy, for it would rise to the ceiling of a lofty room with the greatest ease. Edison, Renard, and Maxim have all done much work on helicopters; and Mr Louis Brennan, inventor of the Brennan torpedo, is busy on similar researches, and at the time of writing has, I understand, constructed a helicopter which will

lift a considerable weight. But the helicopter, to be useful, must not only be able to rise; it must also fly like an aeroplane. This will probably be achieved in the near future.

The aeroplane was the first successful type of flying-machine. As the ornithopter was modelled after the flapping flight of birds, so the aeroplane has been designed to imitate their soaring flight. As we all know, birds that soar, such as the hawks, eagles, and vultures, are much the strongest fliers, and habitually fly at a height



ADER'S FLYING-MACHINE

greater than that attained by the birds that merely flap their wings.

Asked who invented the modern aeroplane, your answer would, no doubt, be the two brothers Orville and Wilbur Wright; but without in the least detracting from the wonderful work done by these two brilliant Americans, the fact is that the real pioneer of aeroplane flight was Clement Ader. So long ago as 1872 this inventor was busy with flapping machines, but, finding them useless, in 1890 he built a real aeroplane with funds furnished by the French Government. Its wings had a fifty-four-foot span, and the machine was drawn through the air by two four-bladed screws driven by a steam-engine of about thirty horse-power. Ader's experiments cost more than twenty thousand pounds, and the result was that when first tried in October 1891 the machine rose and flew for a distance of 164 feet. Seven years later, at Satory

LANGLEY LAUNCHING HIS AEROPLANE FROM THE TOP OF A HOUSEBOAT

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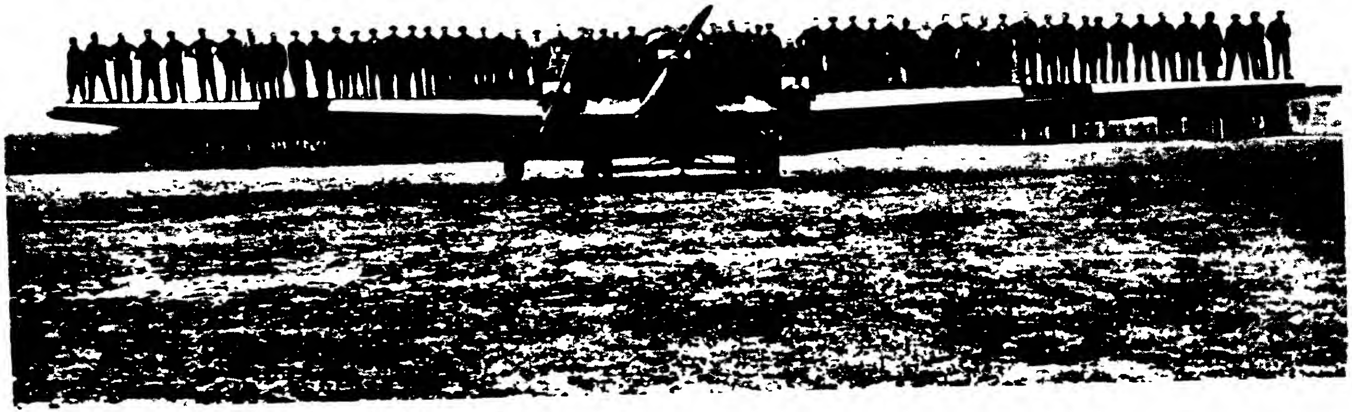


TESTING THE WINGS OF A GIANT MONOPLANE

Photo Keystone View Co.

[*See p.* 209]

in France, Ader's machine made a semicircular flight of nearly a thousand feet. But Ader had not succeeded in getting a proper balance, and both his machines were wrecked for this reason. At the same time Professor S. P. Langley was making his interesting experiments in America, and was working on the lines along which more recent inventors have reached success. Langley built several flying-machines, beautiful little models which he endeavoured to launch from the top of a house-boat anchored in the Potomac River. His engines, driven by steam, were triumphs of strength and lightness. After many failures, on May 6, 1896, one of these models did fly for more than a quarter of a mile. This, mind you, was a very wonderful feat, for the machine was of considerable size, yet did not run along the ground, but had to take off instantly from a height of a few feet above the water. Its pace was nearly twenty-five miles an hour, and when steam gave out it settled quite quietly on the water.

Langley was on the right track, but the trouble was that people at large would not take him seriously. Even thirty years ago anyone who experimented with flying-machines was looked upon as a lunatic.

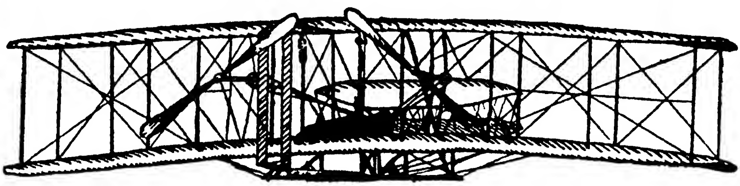
Langley, however, who was President of the Smithsonian Institute, did eventually obtain a grant from the United States Government, and built a man-carrying machine weighing 830 pounds and provided with a petrol-engine of fifty-two horse-power. If only Langley had realized that such a machine required a run to launch it, I verily believe that he, and not the Wrights, would have been recognized as the pioneer of flying. But on each occasion that he tried it, the attempt was made to launch it from the top of a house-boat, and on each occasion it failed to get up the necessary speed and so plunged into the river. Ridicule was heaped upon Langley, and he died, some say, of a broken heart. Fifteen years after this unsuccessful experiment, that is,

in May 1914, Mr Glenn Curtiss, the well-known American flying-man, got Langley's machine out of the Museum where it was kept, fitted it with wheels, and made a successful flight with it at Bath in New York State.

In the nineties a number of experimenters were at work upon gliders. First, Octave Chanute, then the two Lilienthals, and also Percy Pilcher. Gustav Lilienthal and Pilcher were both killed in the course of their experiments, but the work they did proved of immense value to those who came after them.

In *The Scientific American* for May 20, 1905, it is stated: "An aeroplane has been constructed that in all circumstances will retain its equilibrium, and is subject in its gliding flight to the control and guidance of an operator." This machine, constructed by Professor John J. Montgomery, was, however, not an aeroplane but a glider, and it was given its first public trial at Santa Clara, in California, on April 29, 1905. It was sent up in an ordinary hot-air balloon, and at the height of about 4000 feet it was cut loose. Its pilot was Daniel Moloney, a well-known parachute jumper. The thousands who watched from the ground saw Moloney glide downward, making the most extraordinary and complex evolutions. He circled, did figure-of-eight turns and the most hair-raising dives. At times his speed was estimated at nearly seventy miles an hour, yet after a flight of about eight miles he brought the machine to rest upon a spot previously marked out, and so lightly that, although compelled to land upon his feet, he was not even jarred. Octave Chanute saw the flight and so did Alexander Graham Bell, and the latter said positively that all subsequent attempts in aviation must begin with the Montgomery machine. So great was the stability of Montgomery's glider that, on one occasion, Moloney, when in the air, made a side-somersault. Yet the machine righted itself and continued on its regular course.

We come now to the Wright brothers. The Wrights began by reading everything they could find on the work of previous experimenters, and their first glider was a modification of Chanute's biplane glider. They both, however, believed more in practice than in theory, and, choosing a lonely place among the sandhills of the coast of North Carolina, set to work to make experiments in gliding. For many months they were out on every possible day, making hundreds and hundreds of gliding flights from the summits of the taller dunes. They began work in 1896, but it was not until 1903 that they first



THE FIRST WRIGHT MONOPLANE
The first power-driven, man-carrying aeroplane to fly successfully.

fitted a motor into one of their machines. On a dull winter morning, December 17, 1903, they launched their motor-driven glider, and with it made four flights, the longest being 852 feet. This distance was not so great as the flight of Langley's model in 1896, nor as that covered by Ader in 1897. But it was the first time that a power-driven machine had carried a man into the air and had landed safely without accident of any sort.

All through 1904 the Wrights continued their experiments and increased the length of their flights to 1377 feet. It was in 1905 that real success crowned their efforts, for in September of that year they flew a distance of twelve miles in eighteen minutes at Dayton, Ohio, and before the end of the year had increased this to no less than twenty-four miles.

Meantime, others were at work in France, among them Gabriel Voisin, who designed the box-kite type of machine

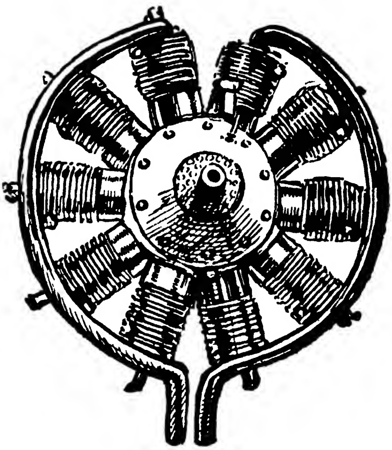
with wireless, by means of which the pilot can be kept informed as to sudden changes in weather.

Quite apart from its use as a carrying machine in peace or in war, every year finds new uses for the aeroplane. For instance, 'planes are used in 'spotting' for fishing fleets. Shoals of herring, mackerel, and pilchards can be easily seen from the air when quite invisible from the shore or boats. In similar fashion, aeroplanes spot the seal herds on the ice off Newfoundland, thus enabling the fleet to sail at once for the scene of action, instead of wasting time searching for the animals. There are swampy districts in Alsace and Lorraine, where the anopheles mosquito spreads malaria. The French sanitary authorities have used aeroplanes to spray petrol on the marshes, and so destroy these deadly insects. In the spring of 1920, when the town of Port Deposit in Maryland was threatened with destruction from flood-water piling up behind ice-barriers on the Susquehanna River, army airmen dropped large charges of explosive upon the ice-barriers, smashed them to atoms, and released the pent-up stream.

In July 1924 there descended at the Croydon Air Station in London a giant Belgian pigeon 'plane which carried hundreds of pigeons in cages. The birds were brought to be released for a flight back to Belgium. They travel, of course, far more quickly and easily by 'plane than by train and steamer. In Mexico, where brigands infest the trails and make travelling dangerous, wages are sent to the oilfields by aeroplane. Laden with bags of gold, the wage aeroplanes hover over the oil-camps until a secret signal is given, and the bags are then dropped by parachute. Money has also been taken by aeroplane to a bank where a run had begun, and where funds were urgently required in order to prevent the bank from being forced to suspend payment. Aeroplanes are being used in the national reserves of the United States

for discovering the location of a forest fire and bringing news to headquarters. Farther north, the forest wardens of the North-west have been flying across the vast spaces in order to watch the migration of the herds of caribou.

But what is, perhaps, the strangest use to which the flying-machine has yet been put is to combat the plant disease known as black-stem rust, which every year destroys two hundred million bushels of North American wheat. The rust spores are so small that they are invisible to the naked eye, and it is therefore most difficult to trace the path they travel as they are blown on the winds. Observers employed by the United States Department of Agriculture have overcome this difficulty by using aeroplanes. Small oil-smeared glass plates are exposed as the 'plane flies across country, and microscopic examination at the end of the journey reveals to the experts the direction of the dreaded enemy's advance.



TEN-CYLINDER ENGINE

The aeroplane was made possible by the invention of an engine of enormous power which at the same time was light and compact. The improvement of these essential features has been the constant aim of all inventors during recent years, and it is difficult to imagine anything more simple than the ten-cylinder engine shown in the accompanying illustration. It was exhibited in Paris on the eve of the War, and was capable of developing 100 horse-power.

CHAPTER XXI

FROM MUSKET TO MACHINE-GUN

The Civilizing Effect of Artillery—Breech-loading—The Flint-lock—Rifling —The Cartridge—Magazine Rifles—The Weapons of Modern Armies.

That it was great pity, so it was,
That villainous saltpetre should be digg'd
Out of the bowels of the harmless earth,
Which many a good tall fellow had destroy'd
So cowardly.

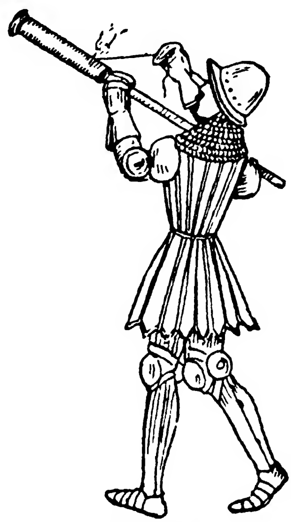
1 Henry IV, I, 3

SHAKESPEARE'S opinion of firearms and explosives has, no doubt, been shared by thousands in every age, yet for all that it must be remembered that it was the invention of gunpowder which brought the Feudal Age to an end. Before its invention, the great keeps of the robber barons were impregnable, and so long as those conditions remained civilization was in chains and liberty was impossible. When cannon loaded with gunpowder were able to batter down the towering stone walls of the castles an unbearable tyranny gradually disappeared.

There is another thing to be said in favour of firearms. In olden days, when the soldier's weapons were the bow and the sword, the art of war was easy and the entire manhood of a tribe or a nation could be turned, if need be, into the field to fight at the shortest notice. But the invention of firearms made the art of war more difficult, and to turn the citizen into the soldier a period of training became absolutely necessary. So, by degrees, instead of every able-bodied man being ordered out to fight, comparatively small standing armies came into being, and before the Great War there was actually less slaughter in

battle than in the days before guns and gunpowder were invented.

Cannon of a sort were used by the Arabs in the 8th century. '*Manjaniks*,' they called them, and the Crusaders brought them to Europe; but, as I have mentioned in Chapter II, these first cannon were of the roughest possible description, and often did more harm to the users than to the enemy. The large-mouthed pieces, built like blunderbusses with a small breech and a wide mouth, were called 'bombards,' while the pieces called 'cannon' had quite a small bore. The projectiles fired were very often nothing but stones, or stones covered with lead in order to make them spherical. Anything like accurate shooting was out of the question. In every case the diameter of the shot was less than the bore of the barrel, and as there was no effective wadding, there was always a considerable escape of gas when the powder was fired. Again, a spherical shot does not travel through the bore of a gun in a straight line, but bumps from side to side, and its direction, on leaving the muzzle, depends upon what part of the bore it has last struck.



HANDGUNMAN, 15TH CENTURY

Breech-loading cannon were known as early as the 16th century, and in the War Museum at Lisbon you may see guns of this type which are more than three hundred years old. Attempts were also made in quite early days to produce a sort of machine-gun. The French *orgue des bombardes* consisted of a number of gun-barrels fixed together upon an axle between two wheels, and, just as in the modern machine-gun, a metal

shield was used to protect the gunners. But this, like other firearms of that period, took a very long time to load and fire. All these early firearms had to be fired by means of a slow-match, and if the weather was wet the chances were all against their being fired at all. At Dunbar in 1650 the English musketeers were unable to fire because the weather was wet and foggy. At another battle, about the same date, we hear of the musketeers firing only seven shots apiece in eight hours!

INFANTRYMAN WITH MATCHLOCK, 17TH CENTURY

The first improvement over the slow-match was the wheel-lock, which was wound up with a key like a watch-spring and, when released, produced a shower of sparks from the impact of steel upon a flint. Following the wheel-lock came the simpler and cheaper flint-lock, which is said to have been invented by robbers who found the slow-match too visible during their night-raids. Flint-locks were used for sporting guns, and were introduced into the British Army by William III. They actually remained in use until the year 1842! The "Brown Bess" used at Waterloo was a fearsome weapon, with a bore of no less than three-quarters of an inch, and weighing, with its bayonet, more than eleven pounds. It was supposed to be good for a range of two hundred and twenty yards, but was so uncertain that the troops were always under orders not to fire "until they could see the whites of the enemies' eyes."

The bullet was spherical and wrapped in a 'patch,' a little square of greased cloth, so as to make it fit tightly in the barrel. The patch also made it easier to ram the bullet into place, an operation which, of course, had to be done with a ramrod.

The first real improvement in the firearm used by the British Army was the rifle known as the Brunswick, introduced in 1835. It was still a muzzle-loader, but was a real rifle; that is, the barrel was made with two deep grooves, and the bullet with a band to fit these grooves. The Brunswick, clumsy weapon as it was, had double the effective range of the "Brown Bess," and the regiments armed with it came to be known as the Rifle Brigade.

Sporting guns with two barrels side by side were first made in Italy in the 17th century, but it is on record that the art of shooting birds on the wing was first practised so long ago as the year 1580.

The copper percussion cap for firing the charge in a gun or rifle was invented about the year 1816, but for a long time was used only for sporting guns and not for military weapons.

The advantages of the rifle, that is, the weapon with a grooved barrel, were recognized as early as the 18th century, but the objection to it was the difficulty of forcing a bullet with a ramrod down the barrel. You will easily understand that, if the bullet was made small enough to drop easily into position, it did not fill the grooves when fired; while, on the other hand, if the bullet was made larger, much time and strength were wasted in ramming it home. In 1852 a Frenchman, Minié, invented an expanding bullet, and the French Government awarded him £20,000 for his invention. As a matter of fact, the well-known English gun-maker, W. Greener, had invented a similar bullet no less than seventeen years earlier. In 1857 the British Government

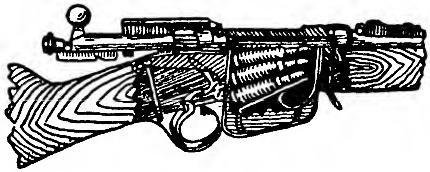
presented him with £1000 as an acknowledgment of his prior claim. The Minié rifle was a great success, for, when tried against the older firearm, 94 hits were made on the target as against only 74 with the musket.

The Prussian Government was the first to arm its troops with a breech-loading rifle. This was the so-called 'needle-gun' invented by Dreyse, and for the first time in military history the whole charge, bullet, explosive, and firing cap, were all contained in one cartridge. It was the needle-gun which gave the Prussians their victories over Austria and Denmark, and which drove the French into adopting the Minié rifle for their whole army.

In 1853 the British authorities began the issue of the Enfield rifle with a smaller bore and a lighter bullet than the older type of musket. The issue of this rifle to native troops in India was one of the major causes of the Indian Mutiny, for it was believed that the grease round the bullet was cow's and pig's fat, the former being defilement to the Hindus and the latter to the Mohammedans. A gun-maker named Snider invented a way of improving the old Enfield rifle and turning it into a breech-loader, and, for a time, the British Army used nothing but the Snider rifle. Then in 1866 the Government offered a prize for a new army rifle, and no fewer than 104 different makers competed. Nine rifles were chosen for a final test, and after a very stiff competition it was decided that Henry's system of rifling with Martini's breech mechanism would make the most serviceable weapon. The Henry rifle, I might mention, afterward became the Winchester, which has long been a favourite in America. The Martini-Henry had seven grooves with one turn in twenty-two inches. It was extremely accurate, and twenty rounds could be fired in fifty-three seconds.

The Martini-Henry was a capital weapon and lasted

for a good many years; but toward the end of the 19th century numbers of magazine rifles had been invented, and these had a great pull over the single-shot rifle in that they could be fired so much more rapidly. So long ago as 1877 the Turks, though very inferior in numbers, were able to repel the Russian assaults at Plevna simply because they were armed with the Winchester repeating rifle. By 1879 nearly every European Power was experimenting with magazine rifles, and the Germans began to rearm with the Mauser. The Austrians adopted the Mannlicher rifle with the magazine in a compartment below the breech. Five cartridges were placed in the magazine in a tin case, which dropped out when the contents had been fired. The cartridges were pressed into the firing position by springs. In England the Lee-Metford magazine rifle (Mark 1) was adopted in 1887, and in 1898 an improved Lee-Metford was introduced. The magazine holds ten cartridges and the explosive used is smokeless cordite.



BREECH OF THE MANNLICHER RIFLE

Immense care is taken in the making of British army rifles. The barrel is inspected or tested no fewer than ten times during manufacture. Seven hundred different gauges are used to check the sizes of the parts as they are made, and these gauges are true within the ten-thousandth part of an inch.

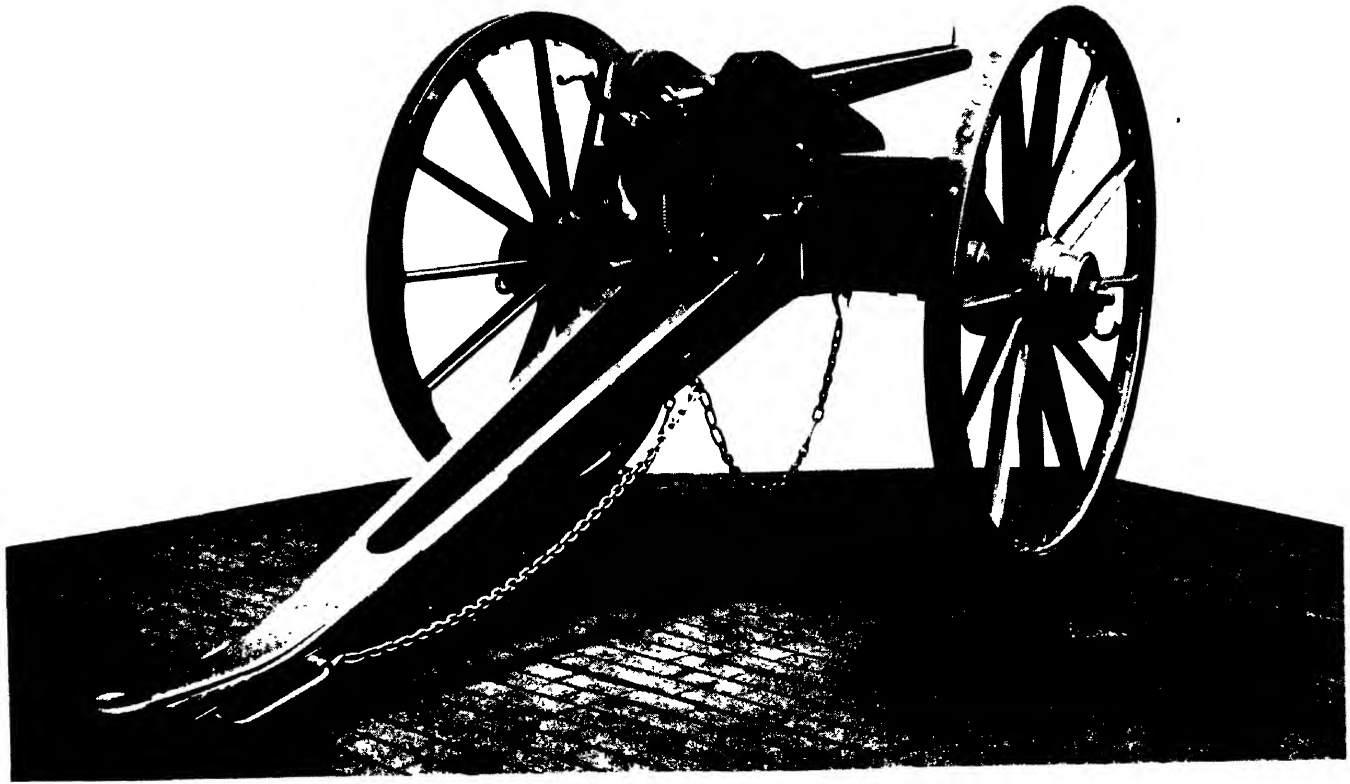
To prevent bullets flattening where they strike, they are coated with a hard metal such as an alloy of nickel. A lead bullet 'mushrooms,' that is, flattens on impact, and produces a most terrible wound. The Geneva Convention has prohibited the use of such missiles in warfare.

I have mentioned medieval machine-guns. The first of modern machine-guns was the invention of Dr Gatling, and was used in the American Civil War, 1862–1865.

The first Gatling gun had ten barrels mounted on a central shaft and revolved by hand. The cartridges were fed into the barrels automatically, and this gun could actually spray bullets at the rate of a thousand a minute. After the Gatling came the Gardner, the Nordenfelt, and Hotchkiss machine-guns, and, late in the nineties of the last century, the Colt and the Maxim. The Maxim was the first machine-gun to have only one barrel, which was kept cool by a water-jacket. Its inventor, Sir Hiram Maxim, very cleverly used the recoil of the gun to extract the empty cartridge and thrust a fresh one into place. It can fire six hundred times in a minute; but if the firing is continuous, the water boils after some six hundred rounds, and after about a thousand requires replenishing. The operator controls the gun by pressure of the thumbs upon a 'button'; so long as this button is held down, the gun goes on firing until the last cartridge is spent or the mechanism jams. The gun can be used either on a three-legged stand or on wheels, and was, at the time of its invention, an immense improvement on any former type of machine-gun.

The Colt gun is an American invention in which the explosion of the charge, not the recoil, is used in its action. The hammer acts like the piston of an air-pump, and, by driving a jet of air through the barrel, cools and cleans it. The whole gun weighs only forty pounds, and I remember attending its first trial in England in 1898, when the late Duke of Cambridge was present. Machine-guns were used in tens of thousands during the Great War, and were very greatly improved. One of the best was the Madsen gun, invented by a Dane of that name—a gun which was very light, and which had one great advantage of most other types in that it very rarely jammed.

The machine-guns principally used by the British



THE FIRST ARMSTRONG GUN, 1855

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JACKET ABOUT TO BE SHRUNK ON BARREL OF ARMSTRONG GUN

Army in the Great War were the Vickers-Maxim and the Lewis. The former was the weapon of the regular machine-gun sections; the latter, a lighter gun, was employed by the infantry.

The Vickers-Maxim is an improved form of the machine-gun originally invented by Sir Hiram Maxim. This was the first of its kind that was entirely automatic; that is, as soon as the trigger was pressed it would continue firing until the magazine, as represented by a belt of cartridges, was exhausted. The rate of fire was six hundred cartridges to the minute, while the whole gun weighed only sixty-three pounds.

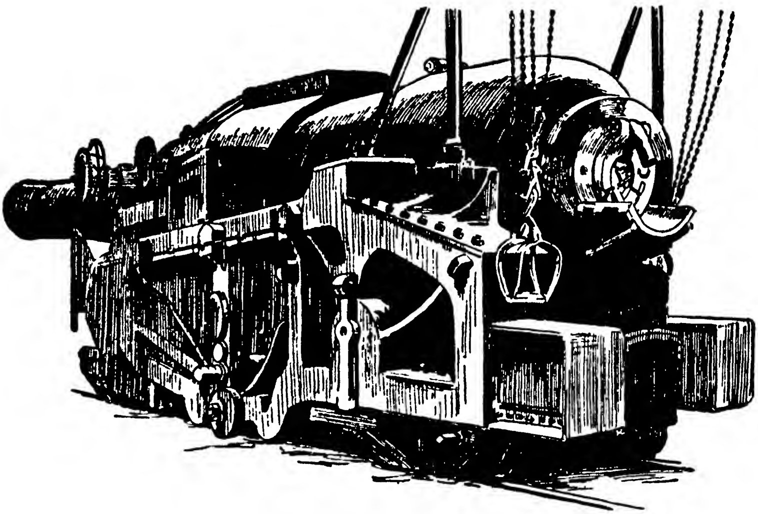
The Vickers-Maxim can fire up to 750 shots a minute, and uses the ordinary Lee-Metford cartridges of .303 calibre; that is, just the same as those used in the rifles of the British Army. It is lighter than the original Maxim, and is sighted to a range of 2500 yards. Now, if you continue firing cartridges at the rate of ten or more a second, the barrel of your gun becomes red-hot, so it is necessary to have some way of cooling it. In the Maxim the method is similar to that employed for cooling a motor engine; that is to say, the barrel has round it a jacket of water. The jacket contains seven and a half pints of water, and it is reckoned that for every thousand cartridges fired, one and a half pints of water are turned to steam.

The Lewis is a smaller, lighter gun, so light, indeed, that at a pinch one man can handle it. Unlike the Maxim, it is air-cooled, and was found invaluable, not only for the infantry, but also for use in all types of fighting air-craft in the Great War.

To turn from rifles and machine-guns to heavy ordnance, it is curious to notice how little real progress there was in the manufacture of cannon right up to the middle of the 19th century. Wellington's troops and Nelson's sailors used cast-iron muzzle-loaders, which fired round balls

packed in greasy clouts so as to make them fit the barrel. Each of Nelson's guns required a crew of at least eight men, who, when a shot had been fired, hauled the heavy gun inboard with ropes, swabbed it out, and recharged it.

Cast-iron was so apt to burst that many experiments were made with brass, bronze, and other alloys. But there was no real improvement until Armstrong of Elswick



110-TON ARMSTRONG GUN

got the idea of *building up* a gun and shrinking over it coils of wrought-iron. This was a great step forward, but not so great as that introduced by Mr Frazer of the Royal Gun Factory, who, in 1869, substituted an inner steel tube in place of an iron one. Then began a great increase in the size of guns. The first was the famous "Woolwich Infant," made in 1872, and weighing thirty-five tons, which was rapidly followed by still bigger guns running up to 81 and even 110 tons. The latter were made at Elswick for the Italian Government, but two were bought by the British Government.

So long as muzzle-loading guns were used they had to

be short, for it was necessary to haul them in for loading. These guns were very wasteful, for the shot left the muzzle before the full power of the powder explosion had been used up. When breech-loading was applied to cannon, the next development was the lengthening of the guns. The original "Woolwich Infant" had a bore only sixteen times its calibre, but modern naval guns are as much as fifty calibres in length. In other words, a gun firing a twelve-inch shell is fifty feet in length.

The progress in gun-building has been truly astonishing, for, whereas in Nelson's time firing did not begin until ships were within a few hundred yards of one another, at Jutland firing commenced at no less than fifteen miles; while during the latter part of the Great War Paris was bombarded from a distance exceeding sixty miles!

CHAPTER XXII

FROM GUNPOWDER TO HIGH EXPLOSIVES

How Explosives aid Man—From Gunpowder to Dynamite—Alfred Nobel's Struggles and Success—Lyddite and T.N.T.

IT is on record that, in order to make a cutting three miles long to drain Lake Fucinus, the Roman Emperor Claudius employed thirty thousand men for eleven years. Many centuries later it took one hundred and fifty years to tunnel nine miles of gallery in a mine in the Harz Mountains. Again, the Spaniards, trying to drain Lake Mexico in the 17th century, failed to accomplish their purpose, although they had a nation of slaves upon whom to draw.

Any of these tasks would have been completed by modern engineers in a few months or, at most, years, the reason being that to-day the engineer has at his disposal a large variety of explosives which in those days were not available.

I have quoted the instances above to introduce the point that, although gunpowder was originally invented and made solely for purposes of war, in later times explosives have been more used for peaceful than for warlike purposes; without them we should not have our modern railways, our great roads, tunnels, docks, or deep mines.

We do not hear of blasting with gunpowder until the 17th century, and even a hundred years later the amount used for that purpose was very small. Gunpowder is made of seventy-five parts of saltpetre (or nitrate of potash), fifteen parts of fine charcoal, and ten parts of sulphur. It is not a very powerful explosive, and is

both dirty and smoky. It acts best when made up into rather large grains. Yet for many centuries it was the world's only explosive, and was not superseded until the discovery of gun-cotton.

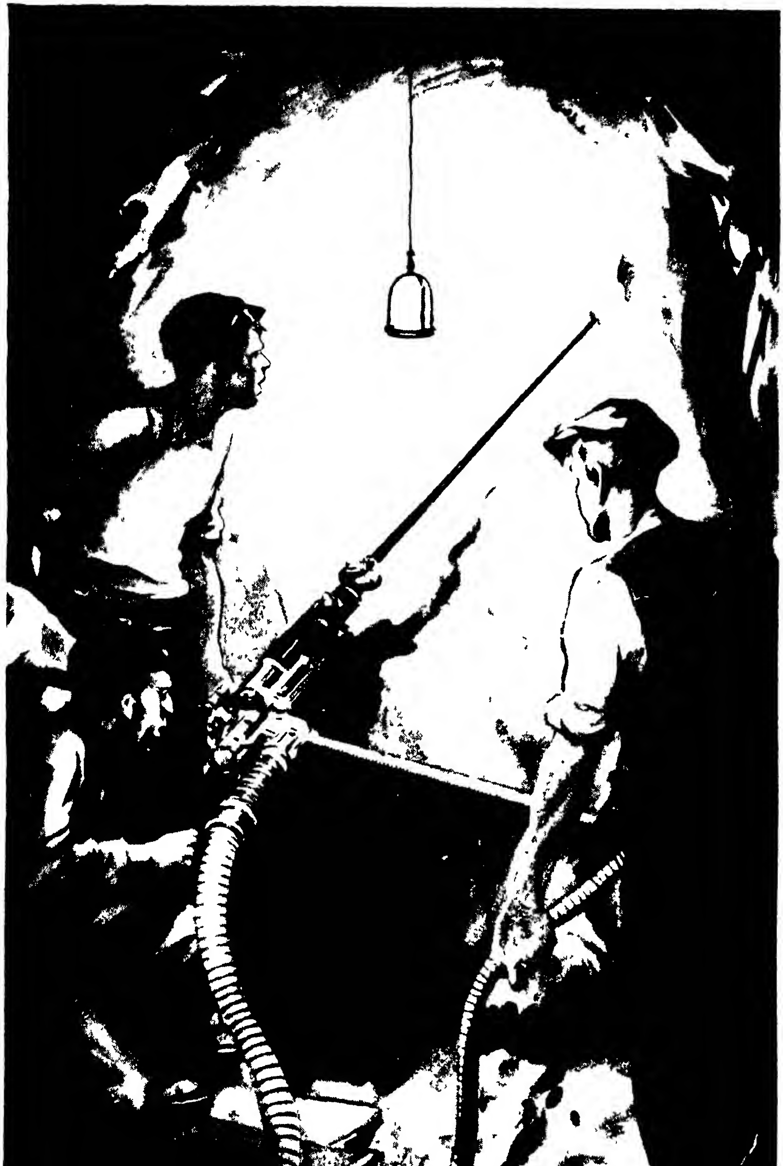
So long ago as 1832 Bracon discovered that woody fibre could be turned into an explosive by the action of concentrated nitric acid; and a few years later a French inventor, Dumas, tried to make cartridges of paper treated in similar fashion. If he had succeeded these would have been the first smokeless cartridges, but he failed; and it was not until 1845 that Schönbein, a German chemist, hit upon the proper method of treating cotton-wool with nitric and sulphuric acids, so as to turn it into gun-cotton.

In 1847 an English firm, Messrs Hall & Son of Faversham, began to manufacture gun-cotton, and military experts hailed it as the new explosive which would take the place of gunpowder. But, as the slang phrase goes, 'there was a nigger in the wood-pile.' In other words, this explosive was so terribly powerful that, when used in a gun or rifle, it blew the barrel to pieces. Worse than that, it was most dangerous to manufacture. There were several small explosions followed by a dreadful one in July 1847, which blew part of the Faversham works to pieces and killed a number of people. The result was that Messrs Hall not only ceased the manufacture of gun-cotton, but also buried their stock in hand. Many further experiments were made, however, but without much result, until the English chemist, Professor Sir Frederic Abel, then head of the Chemical Department of the British War Office, discovered a method of manufacture by which gun-cotton could be completely purified from *free* acid. It was the free acid that had caused the danger of explosion, and Professor Abel's new product was far safer to handle than anything previously made.

Gun-cotton has several advantages over gunpowder.

In the first place, it ignites at a temperature of three hundred degrees, while gunpowder requires a temperature of six hundred degrees to ensure ignition. In burning or exploding it leaves no solid residue, and therefore does not foul a gun-barrel. Also, it is quite smokeless. Again, while gunpowder does not keep well and is ruined by damp, gun-cotton can be kept *under water* without being harmed. Nowadays gun-cotton can be compressed into hard cakes and handled with perfect safety, provided ordinary care is taken. Its explosive powers are tremendous. For instance, if you hang a ring of small cakes of gun-cotton round the trunk of a big tree and fire them, the tree comes down as if a giant hand with a single blow of a monstrous axe had chopped through it. Gun-cotton can be detonated, even when wet, by using a small primer of the dry material, and this fact has led to the adoption of gun-cotton as a charge for torpedoes or for submarine mines.

In 1847 a new explosive came into being. This was nitro-glycerine, made by treating glycerine with nitric and sulphuric acids. But at first it was even more dangerous to handle than gun-cotton, for the least shock exploded it, and its violence was terrific. The great chemist Alfred Nobel tried to improve it by mixing it with gunpowder, but the powder did not absorb all the nitro-glycerine, and accidents of the most terrible kind became more and more frequent. Yet the new explosive, being liquid, could be poured into crevices in rocks, and was so useful as a blasting agent that its manufacture went on until a large vessel carrying cases of the explosive from Hamburg to Chili blew up at sea. The ship was blown to bits and her crew killed, and the disaster caused so great a sensation that the manufacture of nitro-glycerine was prohibited in Sweden, Belgium, and in England. But Nobel still continued his experiments, and at last, after trying sawdust and all other sorts of absorbents in vain, found the perfect



DRILLING ROCKS FOR BLASTING-CHARGES

A 12-INCH ARMSTRONG NAVAL GUN FIRING A CORDITE CHARGE

absorbent in the shape of *keiselguhr*—a sort of earth made of fossil shells. The mixture is what we know to-day as dynamite; and in spite of the fact that modern chemistry has produced very many new explosives, some of terrific power, dynamite remains the safest and most widely used of all explosives.

In 1870 the world's output of dynamite was only eleven tons, but by 1890 this had grown to over twelve thousand tons. To-day it is probable that nearly five times that quantity is being used in a twelve-month. Modern dynamite is made up in sticks consisting of one part of keiselguhr to three of nitro-glycerine. A stick, when touched with a match, burns with a hot flare, but does not explode. It requires a detonating fuse to set it off, and then it explodes so rapidly that the time of explosion has been calculated at only the 24,000th of a second. Used under water, it loses very little of its power, so it can be employed for blasting reefs or sea-rocks.

One great advantage which it has over gunpowder is that there is no need to tamp holes in a rock to receive it. All that is necessary is to lay it upon the rock or other substance which is to be broken up, and cover it with clay. Its whole force is then exerted downward, and it will smash up a rock, a tree-trunk, or a metal casting with equal ease. For quarrying purposes, dynamite is not much used, because it so completely shatters the stone, but for mining it is invaluable. Yet, if safe to handle when made, the manufacture of dynamite is still attended with considerable danger. It is necessary to keep the acids at a low temperature when run together; and if you should visit a dynamite works you will see the various processes carried out in small buildings isolated one from another by heavy banks of earth or sand. All Governments have made stringent regulations for the manufacture and carriage of dynamite.

Nobel did much more than merely discover dynamite ; he also invented blasting gelatine, gelatine dynamite, and gelignite, both of the latter being better suited for rock blasting than pure dynamite. Blasting gelatine was used to pierce the great St Gothard railway tunnel through rock so hard that without it the task could never have been accomplished. Blasting gelatine was tried in guns, but burst them, so Nobel set himself to discover an explosive less violent, yet equally clear and smokeless. By mixing nitro-glycerine and gun-cotton he found a comparatively slow-burning powder which he called ballistite, and this, when he gave it to the world in 1888, caused a very great sensation.

Nobel, though a delicate man, had amazing courage and strength of will. In his early days he experienced all kinds of misfortune. His factory blew up, and afterward he found it almost impossible to get labour, because every one was so terrified of the power of his tremendous explosives ; his younger brother, to whom he was deeply attached, died ; his father became paralysed, and his mother begged him to give up his perilous experiments. He himself suffered agonies from headache brought on by the poisonous fumes of the nitro-glycerine—headaches so dreadful that at times he was forced to fling himself down on the ground in the mine or quarry where he was experimenting, and wait until the agony had somewhat abated. He was extraordinarily brave, and would allow none of his men to take risks that he would not take himself. On one occasion, when a quantity of dynamite was stuck inside a great cask and every one else was afraid to touch it for fear of explosion, he crawled into the cask on hands and knees and dug the stuff out with a knife.

Success at last crowned his efforts, and he made an immense fortune. By the terms of his will, after providing for his friends and relatives, he left over two millions

sterling to provide for yearly prizes for the greatest achievements in chemistry, physics, physiology, medicine, and literature. He died in 1896, and ever since these prizes have been annually awarded. There is no distinction of nationality; the awards are open to men and women of every nation. Nobel's name will live for ever in these prizes, which have done, and are doing, so much to help those who help the world.

Recent experiments in search of explosives which should be both powerful and safe have led to the general use of picric acid as a base. This acid is produced by the action of nitric upon carbolic acid. The French began in 1885 with what they call 'melinite'—a mixture of picric acid and gun-cotton; and the British followed with lyddite, which was first used in Lord Kitchener's Soudanese campaign and a little later in the Boer War. Many attempts have been made to use dynamite in guns; and the Americans at one time built some huge air-guns for the purpose of firing large shells, or rather aerial torpedoes, charged with dynamite. But these guns, of which one or two were used in the Spanish-American War, were very cumbersome and slow in use. Nor could they throw a projectile to a greater distance than a mile. So they were soon abandoned in favour of rifled cannon firing shells loaded with explosives such as cordite or lyddite.

Lyddite is one of the best known of modern explosives, and is very similar to melinite, used by the French, and shimose, the principal Japanese explosive. Lyddite is simply picric acid mixed with vaseline. It is intensely poisonous and highly explosive. Picric acid is one of the many products of coal-tar. It is, in short, a mingling of carbolic, sulphuric, and nitric acids. It has many virtues as an explosive, but also some vices. Its great advantage is that it can be dropped, even thrown about, without any risk of explosion, and that it can even be lighted and

burned in the open without damage. To make it explode, a powerful detonator is required, such as fulminate of mercury. The principal disadvantage of lyddite is that it is intensely acid, so that when moisture is present it attacks lead and other metals, forming explosive compounds which may go off quite unexpectedly.

An explosive of which enormous quantities were used in the Great War is that commonly called T.N.T., which is short for 'trinitrotoluol.' T.N.T. is somewhat similar to lyddite, and though not quite so powerful has the great advantage that it is not *acid*, and so is much safer to store and handle. It is not affected by water or by air, and is so difficult to explode that a rifle bullet fired through it fails to detonate a charge. T.N.T. was first used by the Germans, but afterward by the Allies, especially the British, who employed it more particularly for mines and depth-charges in the anti-submarine war.

CHAPTER XXIII

MOVING PICTURES

How the Human Eye is tricked—Feeling the Way—The Celluloid Film—The Value of the Cinematograph in Science and Industry.

THERE are few modern inventions about which so much has been written as that which we usually call the 'cinema,' and, with the possible exception of wireless, there is none with so great an element of romance. Although only forty years old, there is hardly any other industry which employs more people or a larger amount of money; there is certainly no other which interests or gives pleasure to a greater number. And yet the invention, with all its wonders, depends for its very existence upon the comparative ease with which the human eye can be tricked.

Let me explain. The eye is extremely sensitive to light, so sensitive that it can catch and see an electric spark which lasts but the millionth of a second. It can, as I say, *receive* these impressions with extraordinary rapidity, but it cannot get rid of them with equal rapidity. Indeed, the average eye takes probably about a tenth of a second to get rid of an impression. Take a very common illustration. Char the end of a stick so that it glows, then swing the burning stick round your head, and you get the impression of a circle of fire. Or, again, you see a shooting star entering our atmosphere at a prodigious speed, and glowing white-hot by friction as it flashes through the air. To you or me that meteorite appears like a long streak of light, although common sense tells us that it cannot be in two places at once. Mankind recognized this deception a long time ago, but it was not

until comparatively recent times that any advantage was taken of the knowledge.

In 1825 a little toy was invented, called the ' Thaumatrope.' On one side of a card a horse was depicted, and on the other, but upside down, its rider. The card was spun rapidly by means of a twisted string, and the eye was tricked into seeing one picture of a man mounted on the horse. Then about the year 1860 was invented the ' Zoetrope,' in which a strip with a dozen or fifteen pictures of a man juggling with three balls, or of a child skipping, was placed inside a round box which could be made to spin. In the sides of the box were slits which passed in front of the eye, allowing only one picture to be seen at a time, and the impression was that of a continuous scene of a man juggling or of a little girl skipping. In the ' Praxinoscope,' invented by Reynaud in 1877, and still sold as a toy, the pictures on the strip are reflected in a set of mirrors in the centre of the box.

As an improvement on the Praxinoscope, Mr Reynaud, in 1892, opened an ' Optical Theatre,' which drew large crowds in Paris. On transparent strips 100 to 150 feet long he got artists to draw shadow-pictures of the ' Felix ' kind, which he wound on reels set on a table. The pictures passed in front of a magic-lantern condenser, so as to be brightly illuminated, and a revolving mirror flashed the pictures through a lens. They were thus projected on to a white cotton screen, the spectator sitting on the other side. Another magic-lantern projected the landscapes in which the shadow-pictures fought duels or otherwise disported themselves. Each scene lasted about ten minutes.

In the meantime, with the invention of ' rapid ' dry-plates, referred to in Chapter XIV, it had become easy to take photographs in a small fraction of a second. It was evident that for the production of animated pictures progress lay in that direction, and many people were

working hard at the problem in Germany, in France (Marey, the brothers Lumière), in America (Edison), and also in England.

In the year 1885 the Photographic Society of London was holding one of its usual meetings, and upon a table stood a small contrivance resembling a magic lantern. The only difference was that, instead of slides mounted on the usual carrier, there was a disc of glass which, when held to the light, was seen to be covered with a large number of small, transparent pictures, and these were arranged in the form of a continuous ring. The lights were lowered, and next moment there flashed upon the screen successive pictures projected so rapidly that the audience saw events in real life passing before them. The exhibit lasted but a few seconds, but it was so amazing that for some moments the gathering was still and absolutely silent. Then every one began to ask questions at once.

The exhibitor, quite a young man, was Mr William Friese-Green, at the time a well-known portrait photographer, with a studio in the West End of London, and he had been working for several years on the invention which, now first exhibited, created so great a sensation. The difficulties to be faced were very great, for at that time the modern celluloid film was unknown, and so, too, were metol-hydroquinone developers. Many great inventions have had their origin in very slight beginnings, as we have seen, and so it was with Mr Friese-Green's. One night, when using a magic lantern, he inserted in rapid succession two of those comic slides which used to be so popular. The first represented the face of a man sound asleep; the second, the same face with the eyes wide open. Moving these rapidly to and fro, and watching them with one eye closed, Mr Green observed a certain lifelike action, and the idea flashed into his mind that, if he could get a sequence of pictures

passing at a rapid pace before the eye of the lantern, he might be able to portray motion instead of still life.

After his first exhibition before the Photographic Society, the inventor continued his experiments, and a couple of years later exhibited the apparatus in the window of his studio in Piccadilly. Within half an hour a crowd blocked the entire pavement, and people almost fought to get a glimpse of the new photography. The pictures set working in the window were not particularly exciting, being merely a representation of the Marble Arch with people passing up and down, yet the police had to request the photographer to remove his too-attractive window show because the traffic of Piccadilly was being held up.

Several scientific societies requested Mr Friese-Green to exhibit his new invention at their meetings, but for a long time this first cinema remained no more than a scientific toy. The great handicap to further progress was the glass plates, which were not only heavy and cumbersome, but also very breakable. Mr Friese-Green had already discovered that in order to obtain successful results it was necessary to expose sixteen photographs a second, and the weight of the glass plates made any prolonged exhibition an impossibility. He realized that he must find some substitute for glass, and, like Edison in search of an electric-light filament, he set himself to the task. He prepared scores of different kinds of material, using sheets of gelatine and all kinds of flexible substances, and spent an immense amount of time and money before he suddenly bethought himself of celluloid.

Celluloid, which was at first called 'Parkesine,' was made in 1856 by Mr A. Parkes of Birmingham, and is simply a compound of gun-cotton and camphor or other ingredients. It can be made up to resemble ivory, horn, tortoiseshell, and other substances, and can not only be moulded and pressed into any desired form, but also

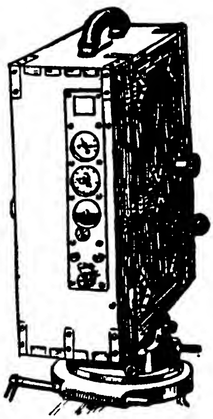
turned, planed, or carved. It is elastic, and is not affected either by air or by water. It has a thousand different uses, for it can be made into billiard-balls, piano-keys, combs, buttons, napkin-rings, brush-backs, card-cases, and many other objects of common use. It can be coloured to represent coral, or made to imitate linen for collars or shirt-fronts.

Mr Friese-Green found it perfect for his purpose, for it was flexible, durable, and could be rolled and packed into quite a small compass. Also, it could be made into rolls of any desired length. The next task was to devise a method of feeding this roll into the camera and jerking it sharply into position behind the lens during the fraction of the second in which the shutter is closed. In this the inventor eventually succeeded, and at last was able to prepare for a real exhibition. Just at this time he was asked to lecture before a learned society, and in this lecture he spoke of the possibility of taking a series of pictures on a long film, but did not assert that he himself had already solved the problem. As soon as he had finished speaking, a distinguished member of the Society rose and proceeded to pull the lecturer's arguments to pieces. It was, he said, absurd to make such statements as Mr Friese-Green had made, for no one could possibly take photographs in the way that had been described. The whole thing, he said, was a fairy-tale.

Mr Friese-Green got up. "I have given you my arguments, gentlemen," he said. "I may save time if I now hand you my proofs." With that he took from his pocket one end of a roll of film and threw the other among the audience. Never did a man look more foolish than the doubter who had declared that the lecturer's statements were fairy-tales.

Mr Friese-Green gave his first demonstration of moving pictures in the year 1890, and to him undoubtedly belongs the honour of being the real inventor of the cinemato-

graph. At the same time, it would be most unfair to forget the good work that other inventors—and notably Mr Edison—have done in the same field. In the year 1887 Mr Edison tried to produce animated pictures by a method similar to that by which he had made sound records on a phonograph. He used a cylinder round which was rolled a sheet of sensitized celluloid, on which were printed a line of tiny photographs. This method not proving convenient, Edison abandoned it in favour of one similar to that first shown by Mr Friese-Green, and at the Chicago World's Fair in 1893 small 'Peep Show' machines of Edison's invention were exhibited and worked on the penny-in-the-slot principle. Mr Edison then perfected the 'kinetoscope,' in which little photographs, each no larger than a postage-stamp, and printed on celluloid film, passed at the rate of no less than forty-six per second. According to Mr F. A. Talbot, Edison did not patent his kinetoscope in England, so credit for the invention of the 'movies' in England must be given to Mr R. W. Paul, well known as a maker of scientific instruments. The story goes that late one evening in the year 1895 a policeman, hearing loud cries in a house in Hatton Garden, called assistance and burst in, expecting to find that a murder was being committed. Instead, he found a small crowd furiously applauding Mr Paul's first moving picture projected on a screen.



ROSS CINEMATOGRAPH CAMERA

As has been the case with so many modern inventions, a number of people were working at the same time, though on somewhat different lines, to solve the problem. The first public exhibition of moving pictures in London was given by two distinguished Frenchmen, the brothers Lumière of Lyons, in the year 1896, and since that date

FILMING A THEATRE SCENE IN THE STUDIO

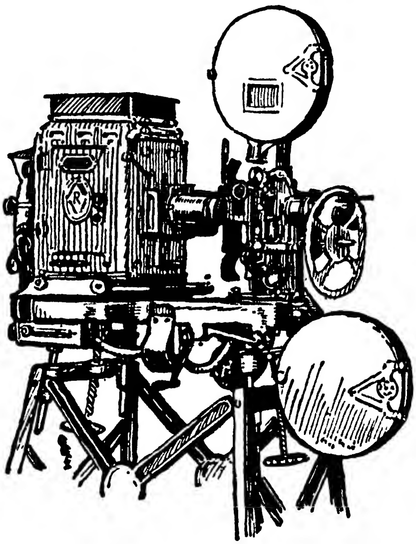
Reproduced from an original photograph by kind permission of Famous Players-Lasky British Producers, Ltd., London

FILMING A 'CLOSE-UP'

By kind permission of the Gaumont Co., Ltd.

scores of different patents in connexion with film photography have been taken out by different inventors.

The modern cinematograph machine still resembles in its essentials the older magic lantern. The film, which is now much narrower than formerly, has holes along the top and bottom to enable wheels with projecting teeth to catch it and pass it through the machine. It goes, of course, in a series of jerks. A disc pierced with a number of holes revolves in front of the lantern, and this disc is geared so that, as each section in succession is jerked into position, a ray of light passes through it to the screen, carrying the picture with it.


THE ROSS CINEMATOGRAPH PROJECTOR

The growth of the cinema has been one of the most amazing features of the present century. At least twenty millions of people go to the 'pictures' every week in the British Isles, and in North America more than double that number. Hardly a day passes without the opening of a new cinema theatre; and not only all towns, but nearly all large villages, have their picture halls or theatres. Enormous fortunes have been made. To give just one example. A good many years ago one of the first of the really big films was produced in Italy. It was from Sienkiewicz's great novel *Quo Vadis?* and was first shown in Rome. An American named Charles Kleine bought up the American rights, and opened a theatre in Chicago with seats for four thousand people. This was packed

at every performance, and at the end of the first week the far-sighted Kleine was $5000 in pocket. At the end of twelve months he had netted nearly $500,000.

Some people think that the cinema does harm, and it is, of course, a fact that films which picture criminals and their doings are far too frequently exhibited. On the other hand, the moving picture may be of the highest educational value. Take, for instance, a travel film like that showing the Mount Everest Expedition. No book could give anything like such a vivid impression of the mighty Himalayas and the strange people who live among their snow-clad heights as does the moving picture. You can sit in your chair and travel over land and sea; you can see an Antarctic blizzard or a sweltering tropical swamp. There pass before you the real people, animals, and scenery of every part of the earth.

Films teach us how to fight disease. We may see how consumption can be treated, how teeth can be kept sound; we may be taught the proper way of getting safely in and out of vehicles and of crossing crowded streets. The wonders of surgery are revealed, and the dangerous activities of the house-fly are brought vividly before our eyes. We can follow a bullet in flight, and see it pierce a soap-bubble. In this wonderful picture it is seen that the soap-bubble does not burst as the bullet strikes it, but as the bullet passes out on the far side. I might mention that in photographing a bullet in flight five hundred exposures are made in one-tenth of a second.

In the so-called slow-motion films the pictures are taken at high speed, but when thrown upon the screen the pace is greatly reduced. Consequently, if the picture presents, say, a man jumping over a hurdle, we see him float leisurely in the air as if he were as light as a soap-bubble. Or, if he is swinging a golf-club, the swing appears to take ten times as long as was actually occupied

in the stroke. Thus, any mistakes the jumper or golfer may have made are clearly seen, and this makes correction easy.

The chief value, however, of the slow-motion camera is not in games, but in industry. For example, it enables managers in factories to study the motion of men loading trucks or working machines, to see just where wrong movements are being made and energy being wasted. By finding out mistakes and correcting them, work is made easier for the employees, and at the same time the output is increased. At present we are but at the beginning of motion-study, but already the debt of industry to the camera is a very heavy one.

CHAPTER XXIV

WIRELESS TELEGRAPHY

The Men before Marconi—A Schoolboy Inventor—Marconi's First Aerial—His Visit to England—The First Signals across the Atlantic—Marconi's Faith in the Future.

AT Dundee stands an obelisk to the memory of James Bowman Lindsay, who died in that city on June 29, 1862. On one of its panels you may read: "A pioneer in electrical science; foretold the application of electricity as an illuminant, a motive power to replace steam, and substitute for coal in heating. He devised an electrical telegraph in 1832; suggested welding by electricity, produced a continuous electric light in 1835; proposed a submarine telegraph in 1843; and accomplished wireless telegraphy through water in 1853."

Lindsay was one of those great men born before their time, and therefore not understood by those among whom they live. It is on record that he not only devised a method of telegraphy without wires, but in 1859 read a paper before the British Association in which he stated that, if wires were run along the coasts of Britain and America and properly charged, he could send wireless messages across the Atlantic. And this, mind you, was nearly thirty years before Professor Hertz made his great discoveries with regard to etheric waves.

After Lindsay, the next experimenter in wireless was Clerk Maxwell, who, in a lecture before the Royal Society, submitted that wireless telegraphy would be possible by means of electric magnetic waves, the velocity of which, he concluded, was the same as that of light, a conclusion consequently proved to be correct. In 1879 Professor

D. Hughes found that a microphone reproduced sound from the telephone when at some little distance from the coils through which the current was passing.

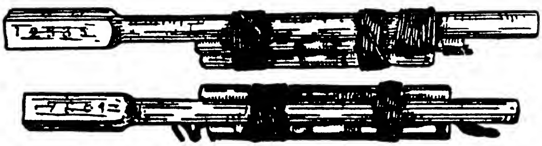
In 1885 that well-known British electrician, Sir William Preece, sent currents between two insulated squares of wire which were a quarter of a mile apart, and in the following year he sent signals between two parallel telegraph wires four and a half miles apart. It was in 1887 that Hertz made his wonderful discoveries. He transmitted wireless signals across a large room by discharging electricity from a Leyden jar; this caused a spark to pass along the terminals of another circuit which had been tuned so as to be in electrical sympathy with the first. Hertz died in 1895, and a few months after his death Sir Oliver Lodge demonstrated to a meeting of the Royal Society that wireless messages could be sent across the lecture-room by means of Hertzian waves, using as a detector or receiver the 'coherer' invented by a French electrician, Branly.

By this time the world of science had become much interested in the wireless waves; but the man in the street, if he had heard of them, was very far from realizing the immense difference they were to make in his daily life.

To Senatore Marconi falls the credit of being the inventor of commercial wireless, and truly he is the Edison of the wireless world. Yet it must not be forgotten that in the year 1892 Sir William Preece had already established communication between the Welsh coast and the island of Flatholm, three and a half miles away, and that without the work of Preece, Hertz, and others Marconi's success would have been impossible. More important than all was Branly's invention of the coherer. Branly's discovery was simply that if a small glass tube loosely filled with metal filings were placed in circuit with a battery and electric bell the current would not

flow through strongly enough to ring the bell. When, however, waves from a Hertzian oscillator were allowed to pass through the filings, the metal particles would cohere, and so permit current to pass and ring the bell. The coherer constituted a detector for the newly discovered waves, and enabled others to go forward in making use of them.

When Professor Hertz was making his great experiments in 1886, Guglielmo Marconi was only twelve years old, having been born on April 25, 1874. But already he was keenly interested in electricity, and, as luck had it, his teacher,



THE COHERER
The first detector used by Marconi for receiving wireless signals.

Professor Righi, was carefully following all that Hertz did. He procured the necessary apparatus, and showed his pupil Hertz's own experiments. The young Marconi was bitten with an intense desire to discover a method of wireless telegraphy, and was not yet fourteen when he had set up rough aerials on either side of his father's garden in Italy. These aerials were simply poles, to each of which was attached a sheet of tin. To the sending aerial he connected one terminal of his induction coil, the other he grounded. Using a spark-gap resonator he was able to receive signals over a distance of about a hundred yards.

It was a great feat for a mere boy, but, as Marconi knew well, others had already done as much, and he was ambitious to do more. Then came the Branly coherer, and this Marconi substituted for his resonator; not only that, but he proceeded to improve it. After many experiments he used a mixture of nickel and silver filings, closing the tube with silver plugs. He devised, also, an automatic tapper for jarring the filings apart after the

passage of each wave impulse. Then he made the further discovery that the taller the aerial, the greater the range, both for sending and receiving.

Before he was grown up, the young inventor was able to send Morse signals by wireless across several miles of space. When he was twenty-one, Marconi made up his mind to go to England and demonstrate there his new invention. He was most kindly received by Sir William Preece, who himself had been working for years at the problem, and through Sir William's influence was given permission to set up his instruments at the General Post Office in London. We can readily credit the statement that every one was astonished that thick walls and roofs made no difference to the transmission of Marconi's signals.

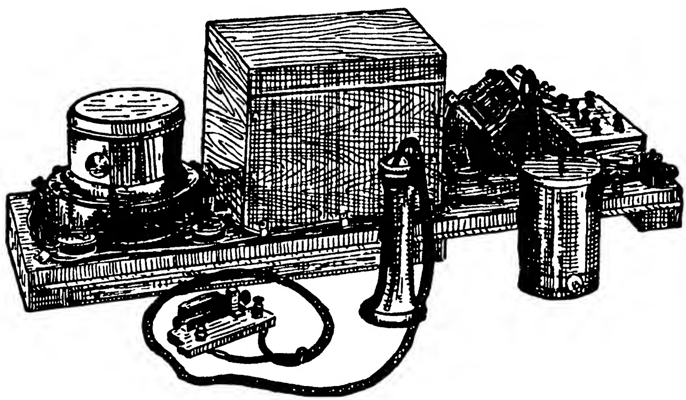
Marconi's first patent for wireless was taken out in 1896, and this brought into the field at least a dozen other claimants, all of whom vowed that they had been before him. Marconi paid no attention ; he simply went on working, and in 1897 conducted new tests on Salisbury Plain ; he also succeeded in sending messages across the Bristol Channel, a distance of about twenty miles. In 1899 he established communication between Alum Bay in the Isle of Wight and Bournemouth or, rather, the Haven, which is the sandy peninsula lying between Poole Harbour and the sea. Here he had a tall aerial in the grounds of the Haven Hotel, and there I used often to see the quiet, grave-faced young man with his curiously intent expression and very lustrous eyes. At that time matters in the wireless world were moving with amazing rapidity, and the papers were beginning to be full of the inventor. In the spring of 1899 Marconi communicated across the English Channel. Then the new wireless telegraph saved a ship in distress in the North Sea. This incident was widely published throughout the world and gave the new invention an amazing advertisement.

Not that Marconi needed advertisement; the British Admiralty was now thoroughly awake to the vast importance of his discovery and paid him the comfortable sum of £20,000 for the use of it in the British Navy. The commercial world had also realized the value of wireless, and Marconi's apparatus was installed on the East Goodwin lightship, off the coast of Kent. Marconi began to amass wealth at a rate unusual for a young inventor, yet it must not be thought that all was plain sailing. He met with much opposition, and his suggestion that it would soon be possible to wireless across the Atlantic was received with jeers as bitter as those flung at the pioneers of flight. The general opinion at that time, even among men of science, was that the distance to which wireless messages could be sent must be limited by the curvature of the earth. This curvature has always prevented and always will prevent long-distance signalling by means of flash lights, the heliograph, and all visible signals, and it was believed that wireless signals travelling in a straight line would radiate out into space and be lost. But Marconi pointed out that if this opinion was well founded, the earth's curvature between St Catherine's in the Isle of Wight and the Lizard would require sending and receiving poles over a mile high; whereas, with poles only three hundred feet high, messages were passing with perfect ease.

Very early in his investigations Marconi was convinced that he would succeed in wirelessing across the Atlantic, and, in spite of all doubts and difficulties, he set himself to proving that his view was correct. A site suitable for transatlantic work was found at Poldhu in Southern Cornwall, and here, at the end of 1900, Marconi began to erect a station, his principal helper being Professor J. A. Fleming. By the following November the station was nearly ready. There were twenty masts, each two hundred and ten feet high, and the current of electricity used

was as much as would have provided three hundred incandescent lamps. The wave generated had a length of about one-fifth of a mile and the rate of vibration was about 800,000 to the second. With this installation Marconi stated that he would be able to send a distance of 2100 miles, and the fact that very few people believed his prophecy disturbed him not at all.

On December 6, 1901, Mr Marconi with two assistants,



THE LISTENING-IN APPARATUS AT SIGNAL HILL

Mr Kemp and Mr Paget, landed at St John's, Newfoundland. No one outside his own party knew that he was now going to try to telegraph across the Atlantic, for it had been given out that he merely intended to communicate with transatlantic steamships as they passed east and west some three hundred miles away. There was no question of building a receiving tower. Marconi meant to send up his wire by means of a kite, and in three days all was ready for the experiment. On December 10 the first kite was sent up—a huge affair of bamboo and silk. But the wind was too strong; the wire snapped, and the kite was blown far out to sea. Marconi next tried a fourteen-foot balloon filled with hydrogen, and sent it upward through thick fog. It had hardly reached

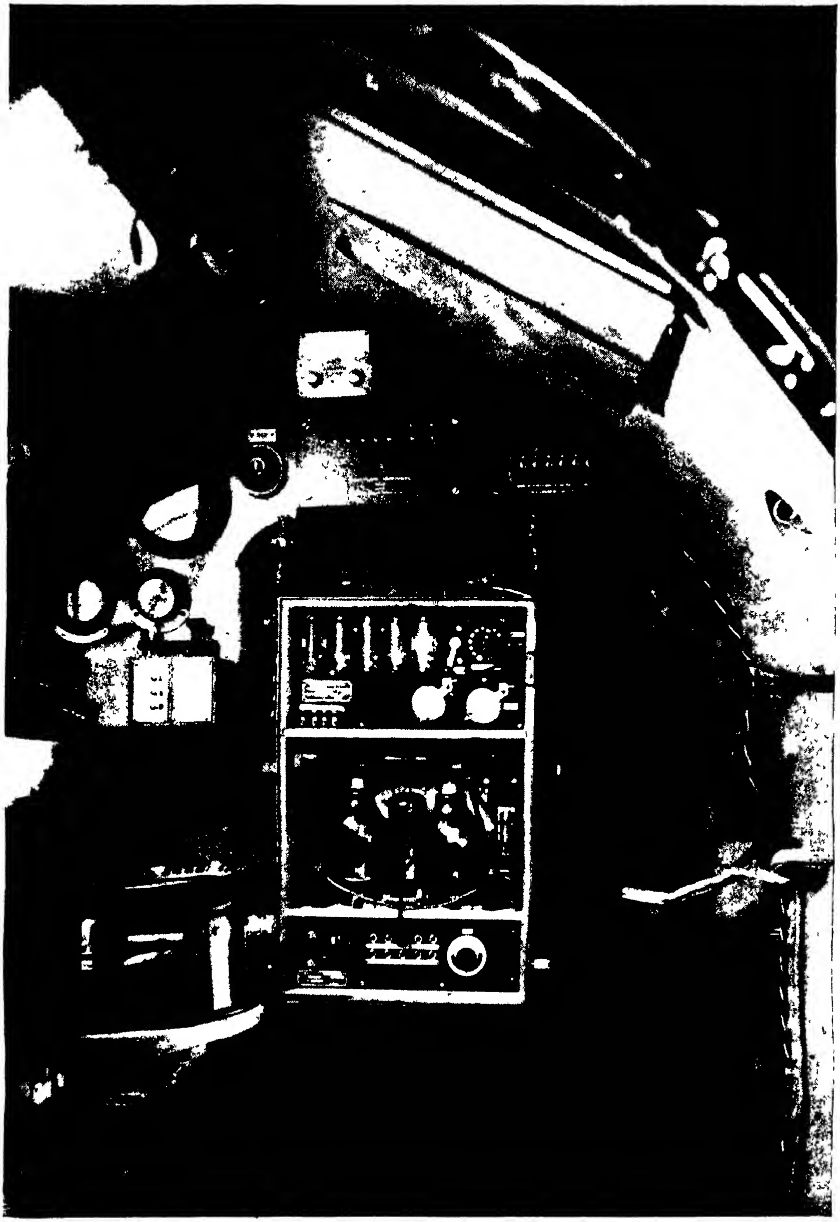
the limit of the line that held it before it too broke away and was never seen again.

The weather next day was too bad for kite-flying, but on Thursday, December 12, Marconi and his assistants managed to get a kite up to about four hundred feet. The wind was blowing in great gusts, but the combined strength of all three men succeeded in holding the kite, and the wire was at last in position and all was ready for the great test.

Before leaving England, Marconi had instructed his assistants that as soon as they received from him a cable stating that all was ready, they should telegraph the Morse S (. . .). He now cabled to Poldhu to begin sending the signals at three in the afternoon (English time), continuing until six. At noon, Marconi sat waiting, a telephone receiver at his ear, in a room of the old barracks at Signal Hill. It was a cold, raw day, with the wind blowing in great gusts and the waves thundering at the base of the cliff three hundred feet below. For nearly half an hour silence reigned in the room, then at last came one sharp click as the tapper struck against the coherer. It was not the agreed signal, merely an indication that something was coming. The inventor listened for a time, then quietly handed the receiver to Mr Kemp. "See if you can hear anything," he said.

Mr Kemp put the receiver to his ear, and a moment later—faint, yet perfectly distinct—came three little clicks, the letter S tapped out a fraction of a second earlier in Cornwall. Again and again it came, and although the kite was jumping madly in the gale and often far below the requisite height, yet the signals continued to come through. On Friday and again on Saturday the signals came, but even then Marconi waited until Sunday before he gave his great news to the Press, and so to the waiting world. Sir Cavendish Boyle, Governor of Newfoundland, himself reported Marconi's

SENATORE MARCONI AND HIS STAFF FLYING THE KITE TO ELEVATE THE AERIAL AT SIGNAL HILL



PILOT'S COCKPIT IN AEROPLANE, SHOWING WIRELESS APPARATUS

By courtesy of Marconi's Wireless Telegraph Co., Ltd.

[*See p.* 251]

success direct to King Edward; and the Cable Company, which had exclusive rights in Newfoundland, alarmed at the great achievement which seemed to threaten its very existence, demanded that Marconi should cease at once from experimenting in its territory.

I have before me a cutting from a London newspaper of December 17, 1901, which gives an interesting example of the way in which the news of Marconi's first wireless message across the Atlantic was received by the Cable Companies. The head of one of the great Companies, a man who had had nearly fifty years' experience of submarine telegraphy, when asked his opinion on Marconi's feat, replied: "I don't believe it. The eccentricity of electric currents are such as might easily lead to a mistake in such an experiment as that of Signor Marconi. With an earth current you often get a repetition of a movement by the transmitter a second and a third time, which might pass for the three dots of an S of the Morse code. . . . Whether Signor Marconi has been successful or not—and I don't believe he has—his system will never have any commercial value, because of the ease with which it can be tapped and the message diverted."

Yes, there were plenty of critics, plenty of objections, plenty of sneers, but Marconi did not trouble to answer them in print. Instead, he proceeded to fit up a receiving apparatus aboard the liner *Philadelphia*, and in February 1902 he sailed from Cherbourg aboard this ship.

Before leaving Poldhu he gave his operators instructions that they should send signals at stated intervals during the week of the voyage. They were to operate one hour out of six, sending messages and signals in periods of ten minutes, alternating with five-minute rest periods. The time was to be the Greenwich Standard throughout, and as the ship's chronometers were set uniform with this it was known to a second when to expect the signals. In one of the four staterooms on the upper deck occupied

by Marconi's party was a table on which stood the receiving apparatus. This was similar to that used afterward on all transatlantic liners, but for sending purposes its radius of action was not more than 150 miles. From the cabin one wire passed through a port-hole, and was fastened to the outside of the ship, thus establishing a ground. For the aerial four parallel wires extended to the top and then over one of the ship's masts, 150 feet above the deck.

The *Philadelphia* sailed just before Saturday midnight, and on the following morning Marconi got into communication with Poldhu. At 250 miles, messages passed freely, and when the ship was 500 miles from Poldhu Chief Officer Marsden happened to be in the operating-room when suddenly a message began to tick out: "All in order." Mr Marsden could hardly credit the miracle, and, running out excitedly, told his brother officers what he had heard.

"Do you think we are going to believe that?" they laughed.

"Wait. You will see and hear for yourselves," retorted Marsden.

A day later the operating-room was crowded. Watch in hand, Marconi opened a brake on the coil of tape, and the white strip began to unroll. "*Tap, tap, tap,*" and Marconi, with a little smile, looked up at the circle of amazed faces. "There it comes," he remarked; and sure enough another message had recorded itself on the tape, waving through the ether from a distance of nearly 1000 miles.

On each subsequent day, at the appointed times, the messages came through. When the ship was 1551 miles from Poldhu, Marconi, with the captain beside him, watched the signals come through in unbroken sequence for ten minutes. The last set came through when the *Philadelphia* was 2099 miles from Poldhu, but Marconi

took it all quite quietly. "I knew the signals would come up to 2100 miles," he said, "because I had fitted the instrument to work that distance."

The year 1902 saw Mr Marconi cruising in the North Sea in a warship lent by the Italian Government, and finding that there was no more difficulty in sending messages across land than water. The whole of France and the towering Alps proved no obstacle to the keeping up of wireless communication with his Italian station. In the autumn of that year Marconi set out for Glace Bay, Nova Scotia, where a big station was being erected; and before the New Year communication was thoroughly established across the Atlantic, many long messages being sent and received. The first, despatched on December 19, was received by Lord Knollys at Buckingham Palace, and ran as follows:

> Upon the occasion of first wireless telegraphic communication across the Atlantic Ocean, may I be permitted to present, by means of this wireless telegram, transmitted from Canada to England, my respectful homage to His Majesty the King?—G. MARCONI, Glace Bay

The following message was received in reply:

> From H.M. King Edward VII to Signor Marconi, Canada.—I have had the honour of submitting your telegram to the King, and I am commanded to congratulate you sincerely from his Majesty on the successful issue of your endeavours to develop your important invention. The King has been much interested by your experiments, as he remembers that the initial ones were commended by you from the Royal yacht *Osborne* in 1898.—KNOLLYS

Since 1902 wireless telegraphy has progressed more rapidly than any other of man's great inventions, and in 1913 began to develop in the direction of wireless telephony, of which I shall have more to say in another chapter. In 1924–5 the biggest wireless station in the world so far constructed was erected at Hillmorton, near

Rugby. There are twelve tremendous masts, each weighing three hundred tons, and standing 820 feet high—that is, more than twice the height of St Paul's Cathedral. The girth of the masts may be appreciated from the fact that each is fitted inside with a lift capable of carrying four men. The new aerial is a mile and a half long and half a mile wide, and will be capable of communicating with any part of the globe.

It is rarely given to any inventor to live to see his invention grow from infancy to stalwart manhood. Marconi began his great work when he was a mere child, and his name was known over all the world at an age when most young men are still completing their university course. Even more wonderful developments of the discovery may be confidently looked for as time goes on. He himself said in an interview which appeared in the *London Magazine* in March 1922: "In twenty years the mysterious, all-pervading ether will be surging with human speech conveyed by ether waves. Whispered conversation with friends in lands as remote as Australia will probably be commonplace, and science having revealed to humanity another wonder of Nature will have forged thereby a fresh link in the much-desired chain of international friendship."

CHAPTER XXV

WIRELESS TELEPHONY

The Thermionic Valve—Broadcasting—The Beam System—New Uses of Wireless.

THERE is hardly any country more isolated than Labrador, and certainly none where conditions of life are harder. Inland lie rocks, bogs, forest, and for eight months of the year deep snow ; seaward, fogs, ice-floes, and storms of the most terrible description. The people who live along this coast are hardy fishermen, most of whom have never seen anything that could be called civilization. In the summer of 1923 a wireless set was installed in one of the fishing villages on this barren coast, and a grizzled old fisherman was asked to listen-in. Through the 'phones there came to his ears the strains of an orchestra playing in a Canadian city many hundreds of miles to the south. The old fellow had never heard an orchestra in his life, and the others watching him hoped to see some signs of pleasure on his face. Instead, he removed the 'phones and laid them down. "'Taint right," he said gruffly. "This here is witchcraft."

Witchcraft ! Well, perhaps the old fellow was not very far wrong, for of all inventions made by man there is truly no other so uncanny as that of wireless telephony. To be able to broadcast a human voice across continents and seas over millions of square miles, in an instant of time, and as fully and clearly as the words were uttered, is, indeed, a tremendous achievement, and one so appealing to the imagination that it is probably for this reason that wireless telephony has progressed even more rapidly than its elder cousin, wireless telegraphy.

In point of fact, there is, however, less difference between the ages of the two inventions than is generally supposed. In 1899 Mr A. Frederick Collins made the first successful experiment with wireless telephony at Narberth, Pennsylvania, when he succeeded in transmitting the human voice to a distance of three blocks of buildings. Later in the same year experiments were made in sending wireless signals across the Menai Strait, ordinary telephonic transmitters and receivers being used. A little later it was found desirable to install telephonic communication between the lighthouse on the Skerries and the coastguard station at Cemlyn, but the bottom of the Channel was so rough and the currents so fierce that a cable could not be laid.

A wire 750 yards in length was therefore erected along the Skerries, and on the mainland facing the rocks another stretch of wire a little over three miles in length. Each line terminated by an earth-plate in the sea, and the distance between the two wires was 2⅘ miles. In this way telephonic communication was established and maintained in all weathers.

Modern 'wireless' depends for its success upon the thermionic valve, which was invented by Dr J. A. Fleming in 1904, and afterward much improved by Dr Lee Deforest. In 1910 Dr Deforest fitted up on the roof of the Metropolitan Opera House in New York a long-distance 'radiophone,' as he called it, by means of which the voices of the singers could be heard at distances up to about a hundred miles. Working with him was Mr Kelly Turner, the inventor of the dictograph—a machine into which letters, etc., are dictated for typing at convenient times. A number of dictographs were installed on the stage of the theatre, and wires ran from them to the radiophone on the roof. "It is now only a question of time," the inventor then stated, "for wireless music and theatre performances, lectures, and church services to be the

common possession of stay-at-homes or travellers at sea."

The truth of this prophecy was demonstrated very soon, for within three years people were speaking to others by wireless over distances up to nearly four hundred miles—for example, between Berlin and Vienna. Words and music were transmitted and heard with great distinctness. In that same year, 1913, successful experiments were going on in England, where Mr Grindell Matthews established communication between Northampton and Letchworth, a distance of forty miles, and the voices were heard as clearly as over the wire. At this time Mr Marconi was experimenting with wireless telephony with vessels of the Italian Navy in the Mediterranean. In 1914 one of the best known of British wireless authorities, Mr A. A. Campbell Swinton, said that the problem of wireless telephony from a commercial point of view was solved, and suggested that the new medium was specially adapted for the distribution of weather reports, time-signals, and speeches. Yet even he could hardly have foreseen that within a few years as many private houses would be fitted with wireless sets as with the telephone.

In 1914 the thermionic valve was in use as a receiver, but as a transmitter it was still in the experimental stage. Then came the War, and with it a rapid, though secret, development of the wireless telephone. The Germans, the French, and the British all used the valve as a detector of wireless waves, with the result that messages sent by land lines to the trenches were open secrets, and new means had to be found for sending them.

Quite early in the War aircraft began to be fitted with small wireless sets, and in these the valve was used for sending as well as receiving. And so came into being the three-electrode thermionic valve, which consists of a vacuum bulb similar to an electric-light lamp, but having

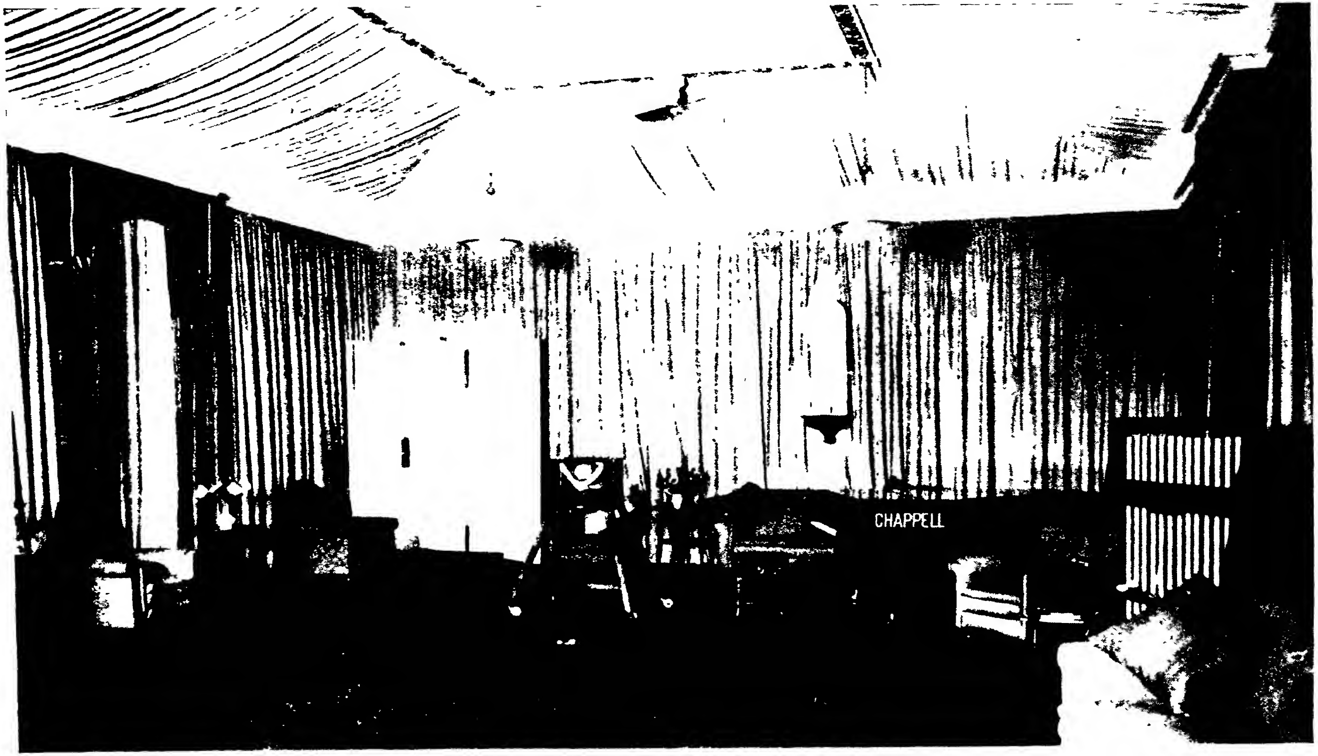
two other metal elements inside the bulb in addition to the filament. Toward the end of the War aeroplanes were communicating with their ground-stations up to a distance of fifty miles and up to five miles with each other. By 1921 these distances had been doubled, and they have since been still further increased. Aeroplanes can now communicate with each other by telephony from 50 to 100 miles and can speak to aerodromes as far as three or four hundred miles away.

One principal development of the valve was that of direction-finding. For this purpose the currents at a receiving station are so arranged that, on signals being heard, the direction of the sending station is at once known, and, if required, its exact position can be found by plotting its direction from two or more receiving stations.

The first occasion upon which audible speech crossed the Atlantic was during the War, when messages from a station near Washington were heard in Paris, a distance of 2300 miles; to-day there is no ocean so broad that the human voice cannot be carried across it by wireless waves, and no place so remote but that its inhabitants can keep in touch with the rest of the world by wireless.

The British Broadcasting Company began a regular broadcasting service from London on November 14, 1922, and now also operates from many stations at different centres throughout Great Britain. Its concerts, etc., have reached the ears of listeners-in, amateur as well as professional, in the remotest parts of the world.

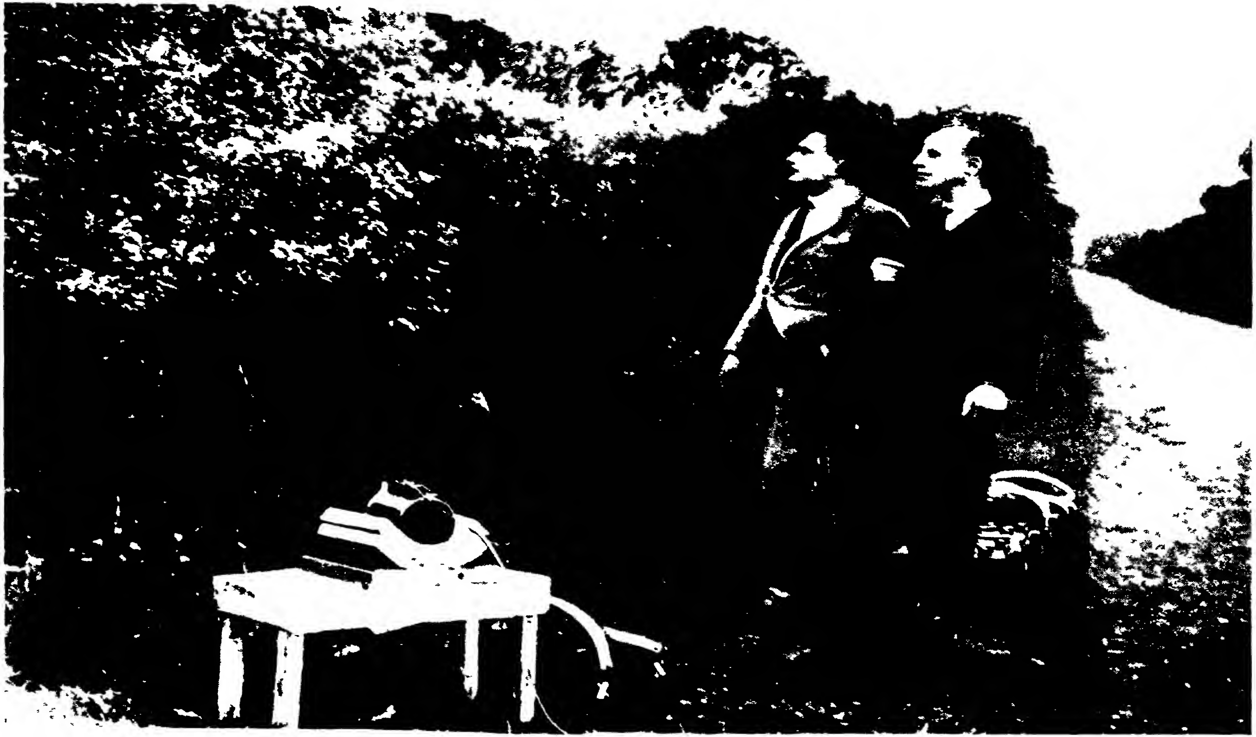
Similarly, American concerts can be heard all over England, as well as in Australia and elsewhere, and broadcasting on a large scale is being constantly extended in all parts of the world, including Australia and New Zealand and various states of South America, also Japan. It seems certain that the future has in store wonders of wireless far beyond anything already achieved. In 1924 Mr Marconi's experiments with the 'beam' system were



THE LONDON STUDIO OF THE BRITISH BROADCASTING COMPANY

The microphone stands in the centre.

By courtesy of Marconi's Wireless Telegraph Co., Ltd.



BROADCASTING THE SONG OF A NIGHTINGALE

By courtesy of Marconi's Wireless Telegraph Co , Ltd.

brought to a considerable pitch of perfection. By this newer system wireless waves can be concentrated in a beam somewhat like the way in which the rays of a lamp are concentrated by a reflector. This results in an immense saving of energy over the old system, whereby the rays are broadcast in all directions.

An interesting experiment was made during 1924. On several occasions mysterious signals had been received, which some believed had come from another planet—possibly Mars. In August 1924 experiments were made with the object of endeavouring to receive any such signals. The set used contained twenty-four valves, and was the largest and most powerful ever constructed. No definite signals were obtained from Mars, but the experiment gave other interesting results.

Trade statistics prove the enormous popularity of wireless; in Britain and the United States alone innumerable firms are manufacturing wireless sets or accessories. Perhaps in the United States more than in any other country wireless is revolutionizing daily life. At the end of 1924 it was reckoned that there were nearly five million sets of receiving apparatus in use, or five times the number of licences taken out at that date in England. The United States was first to fit out private cars with radio. In England police cars are fitted with wireless, which is a great help to the so-called 'Flying Squad' in running down offenders; and in Austria transmitters are installed at headquarters of the Fire Brigade with receivers on the engines. In this way the fire-chief can keep in constant touch with his subordinates.

The uses of wireless are endless and are constantly being extended. Wireless saves the lives of men at sea, tells the weather daily, helps to make flying safe, especially in fog, and gives the correct time to clocks all over the world. Experiments made in one of the deepest of Staffordshire coal-mines showed that communication

between the pithead and the men working thousands of feet below in the depths of the earth can be easily established and kept up with portable sets. Wireless may, therefore, save life in coal-pit disasters, for if men imprisoned by a fall of earth can wireless their position, delay in getting help may thus be avoided.

There is on record a case of the kind which is so strange as to be worth recording. During the War a party of British engineers burrowing in no-man's-land were suddenly entombed by an explosion. One of their number had a small wireless set with which experiments were to be carried out below ground. The range of this set was small, but as a last resource it was decided to broadcast a message on it. The message was picked up by a British 'plane travelling high in the air above the battlefield. Help came in time, and all the party were saved.

No one may safely prophesy as to the future of radio dynamics. If sound can be sent without wires, why not power also? So long ago as 1914 Mr Marconi announced that he could light a lamp by wireless at a distance of no less than six miles. The famous American inventor Mr Nikola Tesla has long been busy on the great problem of transmitting electric power through the ether without wires, and some of the results already reached are extremely startling.

CHAPTER XXVI

RADIUM AND THE X-RAY

Professor Röntgen's Discovery—The Triumph of the Curies—How the X-Ray detects Fraud—Its Value in Science.

RATHER more than thirty years ago there came to Paris a young Polish girl named Marie Sklodowska. Her father had been a man of science, and she had been brought up in his laboratory, but a revolutionary plot had broken up her home and forced her to take refuge in France. She was very ambitious of completing her scientific training, and, to enable her to do so, obtained work in a laboratory, where she washed bottles for a bare living, feeding on bread and milk, all the time working long hours of the night at her studies in order to pass her examination for a degree in science. At the University she met a young French student named Pierre Curie. They fell in love, and in 1895 were married. Together they worked hard and steadily, and in 1898 Madame Curie received her degree, and she and her husband turned to original research.

The particular study which interested the young couple was that of the rays given off by vacuum tubes. Twenty years earlier, in 1879, the English scientist Sir William Crookes had discovered that the negative pole of a vacuum tube, when excited by high-tension electricity, gives off rays of a very peculiar order. He named them Cathode rays, and they were afterward shown to consist of particles of negative electricity known as electrons.

Other men of science experimented with these rays, but it was not until 1895 that Professor Röntgen announced that he had obtained from a vacuum tube a

new light which was able to penetrate many substances hitherto regarded as opaque. The heaviest black paper was no bar to their passage, and the rays were able to affect a photographic plate. No scientific discovery ever made a greater appeal to popular imagination, and few have had greater results. The new rays opened up a whole new field to the surgeon and the doctor, who now, for the first time, could see a broken bone without first cutting through the flesh, or could watch the movement of food in its various stages in process of digestion. A hundred other uses soon appeared, of which I have more to say a little later on.

The discovery of the X-ray led a friend of Madame Curie to investigate the light-giving properties of phosphorescent substances. This young scientist, Monsieur Henri Becquerel, used the metal uranium as the subject of his experiment. After exposing a piece of uranium to sunlight he then placed it upon a photographic plate which was thickly wrapped in black paper. When developed, the plate was found to be affected, so there was no doubt but that here was a radiation similar to the X-ray. Becquerel tried again, using thin metal plates instead of black paper, and got a similar result.

On the following day Becquerel meant to try a fresh experiment, but the morning turned out dull, and since there was no sun he thrust the piece of uranium and his photographic plate into a drawer, and, busy with other work, forgot all about them. Days later he opened the drawer, and it occurred to him to develop the plate and see whether there had been any action upon it, even though the metal had not been first exposed to sunlight. He found there had, and so made the discovery that uranium itself gave off rays capable of penetrating dark matter. Becquerel told Madame Curie of his discovery, and she, greatly interested, set herself to examine other substances and see whether any besides uranium possessed

radio-active properties. She did find one in the shape of thorium—a rare earth used in making incandescent mantles; and presently a second, namely, pitchblende, which is the parent ore from which uranium is obtained, and in this—imagine her amazement!—the degree of activity was no less than four times as great as that due to the uranium contained in the sample. The conclusion was plain, namely, that pitchblende must contain some other substance, probably an element, which was more radio-active than uranium.

At once Madame Curie decided that she would discover the nature of this substance, and she and her husband began work. The material for the experiment was presented to Madame Curie by the Austrian Government. It was a ton of pitchblende from the Government's own mines. Pitchblende is one of those raw materials which are a natural storehouse of many different prime substances, and the task of separating all of these out of twenty hundredweight of hard rock was a tremendously heavy one. It required large quantities of coal, great tanks of distilled water, and many costly chemicals. Above all, it required much knowledge, extreme care, and weeks of very hard work.

Beginning work in a large building, the mass of material slowly decreased until the test tubes of the Curies' laboratory could hold the results. Then came Madame Curie's first discovery—that of a new element, which she named polonium, after her native country. But electroscope tests showed that there was a still more active element in the residue, and for months the patient investigators hunted it until, in 1898, they separated out that most marvellous of all elements, radium. Radium proved to be two and a half million times more active than uranium. It not only affected photographic plates, but ionized the air, excited phosphorescence, and liberated heat. It was even able to destroy life, although this knowledge came later.

The Curies did not *invent* radium, for radium is as old as the world. What they did was to discover it, and this is generally allowed to be the greatest chemical discovery made by man. While the element itself is capable of performing what seem like miracles, its principal value is the light which radium throws upon the structure of the atom and other deep secrets of chemistry.

In 1903 Madame Curie was awarded a doctor's degree by the University of Paris, the Davy Medal was awarded to her husband and herself, and they also received one of the Nobel prizes. In 1906 Professor Curie was killed in a street accident, and Madame Curie succeeded to his professorship at the University.

Many other scientists have been busy investigating the properties of radium. It was Becquerel who, quite by accident, discovered the fact that the element can burn. He had been carrying an atom of radium salts no bigger than a pin-head in a glass tube in his pocket, and presently discovered a sore place on his body just behind the pocket. It was soon proved that radium rays produce very remarkable results upon animal cells, and one of the first discoveries made was that radium is a cure for warts. One good application of radium puts an end to any wart. From this discovery sprang the radium treatment of cancer and other similar diseases.

Radium, it is now known, emits several different kinds of rays. The Alpha rays are stopped by a sheet of paper, the Beta rays by a thin sheet of tinfoil, but the Gamma rays will penetrate a steel bar or a door. It is to the great English scientist Sir Ernest Rutherford that science owes its knowledge of these different rays. The Alpha rays he showed to be positively charged particles shot out at a velocity of about 20,000 miles a second. The amazing part about them is that they have been proved to be positively charged atoms of helium, and so, for the first time in the history of the world, the old dream of

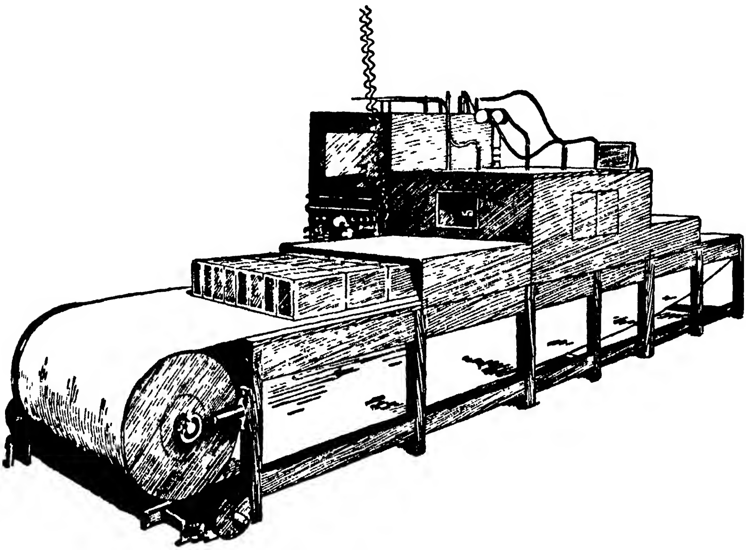
the alchemists has come true, and we can watch one element change into another. Beta rays consist of streams of electrons travelling at much greater speed, while the Gamma waves are waves in ether similar to X-rays, but shorter.

When radium was first isolated from pitchblende this was supposed to be the only source from which it could be obtained. It is now known that, so far from being confined to one particular geological formation, radium exists everywhere in all rocks and in most water. True, the quantities are very small, for even in pitchblende, which is richer in radium than any other deposit, radium exists only to the extent of one part in two millions. And so difficult it is to obtain that thirty tons of pitchblende yield only one-tenth of an ounce (about one part in eleven millions) after operations lasting for more than two years. In the year 1921 the women of America presented Madame Curie with a gramme (about a thimbleful) of radium. In order to obtain this amount six hundred tons of ore were treated, and the labour of five hundred men was required for six months. The process of extracting this tiny amount of radium consumed ten thousand tons of distilled water, a thousand tons of coal, and five hundred tons of chemicals. Is it to be wondered at that diamonds or rubies are cheap as dross when compared with the value of radium ?

Whether radium will ever be extracted in quantities large enough for commercial use is a question that at present is without answer. And even if we do find ways of obtaining radium by the pound instead of the milligramme, such large masses would be extremely dangerous to handle.

On the other hand, the X-ray discovered by Professor Röntgen has scores of different uses, and fresh ones are constantly being discovered. The Post Office, for instance, finds it invaluable. Dangerous drugs, such as cocaine,

used to be sent through the post, most carefully hidden. A favourite hiding-place was a book, the centre of which was hollowed out and the drug placed in the cavity. Formerly the postal officials took an immensity of time and trouble in their search, and if mistaken were often obliged to pay damages to the owner; to-day the X-ray



CIGARS BEING TREATED UNDER THE X-RAY

reveals in a moment if any smuggled object is hidden in an innocent-looking package.

Cigar manufacturers are using the X-ray for killing small insects which bore holes in cigars. The cigars, packed and ready for shipment, are run through a lead-lined chamber upon a continuous belt; they remain about five minutes under the rays, and this destroys the insects or their eggs.

All sorts of clever frauds are made up for sale to collectors, especially mummies. In old days it was next to impossible to discover these frauds, but now the eye of the X-ray camera detects them in a flash. Indeed, the

X-ray has almost destroyed the once considerable trade in fraudulent mummies, and it has actually hit the drug-smuggler much harder than all the legislation on the subject.

Not only surgeons, but dentists, find the X-ray of the greatest value, for by the use of a radiograph the state of the roots of a tooth can be seen without pulling it out of the jaw. Even shoemakers use X-rays; a customer may be shown the bones of his or her foot after a new shoe has been fitted.

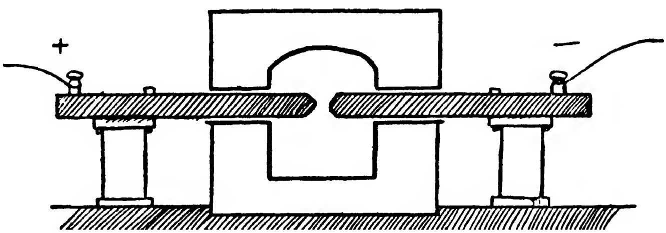
CHAPTER XXVII

THE ELECTRIC FURNACE

Moissan's Great Work—What we owe to the Electric Furnace—The Blow-pipe—The Thermit Process.

SOME metals, such as tin and lead, melt at very low temperatures. Silver, gold, and copper require greater heat, yet all melt at or about a temperature of a thousand degrees centigrade. Iron is more difficult, for it takes a temperature of 1600 degrees centigrade to melt wrought-iron, while metals of the platinum type demand still higher temperatures to reduce them.

Until the invention of the blast furnace, man had at his command no way of obtaining a heat fit for making steel, and even in a blast furnace the temperature does not exceed 1600 degrees C. Fifty years ago chemists and others were already realizing the need for higher tempera-



A SIMPLE ELECTRIC FURNACE

tures, but the question was how to get them. In the year 1892 Henri Moissan, a French chemist attached, like the Curies, to the University of Paris, had made a rather rough electric furnace of the 'resistance' type, so termed because the heat is produced by the high electrical resistance of the material with which the furnace is charged. A little later Moissan went to work on different lines, and

constructed an arc furnace in which the current is led in by two carbon rods which meet just above the substance under experiment. The points in contact are raised to a white heat, and are then separated, whereupon the electric current bridges the gap and an immensely high temperature is produced.

The body of Moissan's furnace, also the lid, were constructed of blocks of lime, lime being one of the most perfect of non-conductors of heat. With this comparatively simple device, but using a powerful current, Moissan found himself able to command temperatures up to 4000 degrees centigrade. The lime itself began to melt, and the heat of the central furnace was so intense that it was necessary for the operator to wear glasses to protect his eyes. Ordinary metals did not merely melt; they actually boiled. When copper was placed in the furnace, flames of green copper-gas streamed out of the holes through which passed the carbon rods.

In Siemen's furnace it had taken an hour to melt a pound of iron, but in Moissan's the metal was fluid within three minutes. Moissan next began to experiment with unyielding substances such as chromium, manganese, tungsten, vanadium, and silicon. These had hitherto been mere chemical curiosities, obtainable only in very small quantities; but the new furnace provided a means of obtaining them in larger quantities, and in this way proved of immense value to mankind. These substances, you see, have the power of influencing steel when mixed with it in proper proportions. Chromium makes steel extraordinary tough, manganese and tungsten make it hard, vanadium gives it strength. A great deal of the steel used for the frames of motor cars is strengthened by the use of vanadium. Mix silicon with steel and you get a metal suitable for making springs.

Moissan's electric furnace was the starting-point of a new age in steel manufacture. Modern guns, armour-plate

cars, and high-speed tools could never have been made had it not been for the developments here mentioned.

Another of Moissan's achievements was the manufacture of artificial diamonds from carbon. These diamonds were but the tiniest fragments of crystalline carbon, and were enormously costly to produce. Moissan's method of making them was to dissolve coke-dust in molten iron, using a crucible made of carbon. When the intense heat of the electric furnace had rendered the whole mass fluid, the crucible and its contents were suddenly dashed into cold water. The sudden cooling of the iron set up such tremendous pressure that the melted carbon was crystallized and turned into minute diamonds. The precious stone which we call the diamond is nothing but pure carbon (or charcoal) in a crystallized form.

Natural graphite, commonly called blacklead, is another form of carbon. In its natural form it had always been scarce, yet new uses for it were constantly appearing. It was needed not only for lead pencils, but for stove blacking, for electrical appliances, and, above all, for lubricating purposes. Before the invention of the electric furnace the idea of manufacturing graphite would have been scouted as ridiculous; but once Niagara was harnessed, and its huge electric power made available, the operation became as simple as making soap. Graphite being merely pure carbon, by treating anthracite coal in the electric furnace the hard black lumps are turned into a fine black powder, greasy to the touch, and capable of a hundred uses. To-day every ounce of blacklead used for polishing a kitchen range or stove is the product of one of these wonderful electric furnaces.

Some years before Moissan made his attempts at turning black carbon into crystal diamond, another experimenter was in the field. This was Mr E. G. Acheson, one of Mr Edison's band of brilliant young chemists.

Not having electric heat, he made use of the oxy-hydrogen flame, and perhaps for that reason failed to produce diamonds. Later, Mr Acheson was one of the pioneers of electric lighting in Europe, and installed the first electric-lighting plants in Milan, Genoa, Venice, and Amsterdam. When this work was finished he returned to America, and was placed in charge of the new power-works at Niagara. The amount of electricity obtained from this mighty fall of water was far greater than any yet procurable, and Mr Acheson decided to make a fresh attempt at the production of artificial diamonds. But he had also another object in view. At that time emery (oxide of aluminium) was the material in universal use for grinding down rough metal castings, and Mr Acheson thought it might be possible to produce some hard substance which would do the work of emery. Such a material, if it could be cheaply made, would certainly have great value.

After considering the matter, the chemist believed that carbon mixed with clay would produce an extremely hard substance, and that if, in cooling, the carbon should separate from the clay, the result might be real diamonds. He therefore mixed clay and coke-dust together, placed them in a crucible, inserted the ends of two electric-light carbons into the mixture, and connected the carbons with a dynamo. The fierce heat fused the clay and carbon together, and, when the resultant mass had been cooled, a few small purple crystals were found. These were so hard that they scratched glass; but after examining them, Mr Acheson was sure they were not diamonds. He thought, however, that they might be rubies or sapphires. He then repeated this experiment, getting similar but larger crystals, and these, to his amazement, proved to be harder than rubies, even scratching the diamond itself. He showed them to jewellers, chemists, and geologists, who nearly all pronounced them to be

natural gems dug from the bosom of Mother Earth. One of the authorities to whom they were shown was Professor Geikie, the celebrated Scottish geologist. After he had examined them he was told that the crystals had been manufactured in America, but this statement he flatly refused to believe. "Those Americans!" he exclaimed quite crossly. "What won't they claim next? Why, man, those crystals have been in the earth a million years."

Mr Acheson named his new gems 'carborundum,' and soon found that he had discovered exactly what he had been looking for, namely, a cheap and perfect substitute for emery. In 1893 he made seven tons of carborundum, and by 1902 was producing no less than 2700 tons yearly. The mixture used is 34 per cent. coke, 54 per cent. sand, 10 per cent. sawdust, and 2 per cent. common salt. After the cooling the carborundum is found in large crystals 'round the carbon core; and outside is another substance, called 'siloxicon,' which is used for furnace linings. The furnaces used for making carborundum have to be built up afresh for use each time. The heat is so terrific that many of the bricks melt like cheese, and new ones must be supplied.

The heat produced in the electric furnace is probably equal to that of the sun itself, and is no doubt amply sufficient for the production of diamonds. Science, however, has not yet learned Nature's secret of producing the gigantic pressure which is equally essential.

Far more important than carborundum is another product of the electric furnace called 'calcium carbide.' This was first made by accident at the works of the Cowles Electric Smelting Company at Cleveland, Ohio. On the dump were found some lumps of porous grey stone which, when dropped into water, gave off a gas which exploded at the touch of a match. Calcium carbide is produced simply by heating together carbon and common

lime. The two unite into a sort of extremely hard and heavy greyish stone, the great value of which is that it gives off, when damped, the gas called acetylene. Acetylene burns with a white flame, giving a most wonderful light strongly resembling that of the sun; and many private houses all over the world are lit with acetylene gas, which is very simple and easy to make and store. It is even more simple to burn, for it does not require a mantle, as does coal or petrol gas.

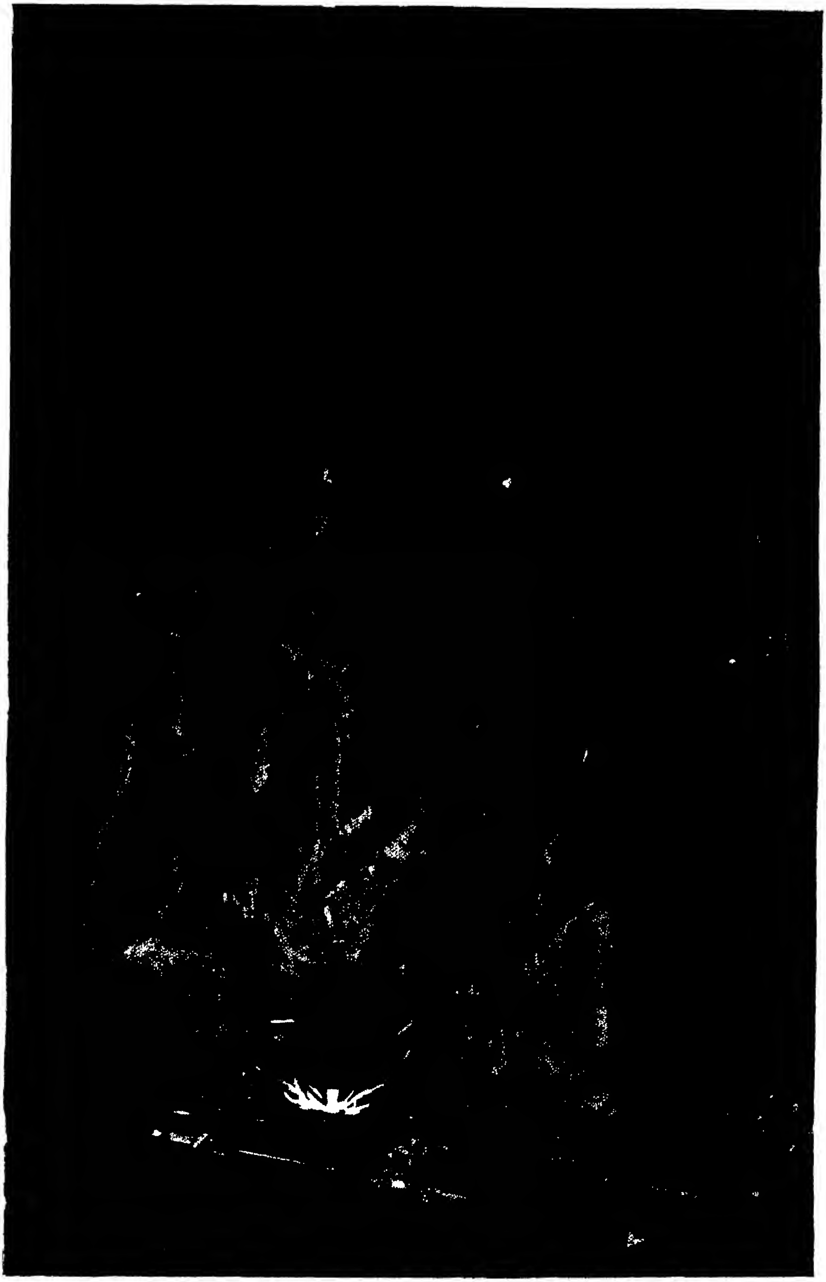
SAFETY DRESS FOR USER OF OXY-ACETYLENE

But the great value of acetylene gas is for welding purposes. Previous to the discovery of acetylene, welding was accomplished by means of the oxy-hydrogen blow-pipe flame, by which a temperature of 2000 degrees centigrade could be obtained. But with acetylene, which is more easily handled and cheaper, a flame twenty per cent. hotter could be obtained. With the oxy-acetylene blow-pipe a man can attack sheets of armour-plate up to a thickness of an inch and a half, and cut it like cheese. An elliptical man-hole—say sixteen inches by ten inches—can be cut in a one-inch boiler-plate by this method in four minutes, and an armour-plate six inches thick can be cut at the rate of a yard in ten minutes. For repair work, and especially for repairing damaged battleships, oxy-acetylene is simply invaluable. It must, however, be confessed that the discovery has another and less pleasant side, in that it has been adopted by criminals; the oxy-acetylene

flame has been used again and again by safe-breakers to open steel safes. Workers with the oxy-acetylene blow-pipe have to take precautions against the intense heat and dazzling glare. They must wear blue glasses, and work behind a shield, for otherwise they would very soon be blinded and scorched.

Even now we have not come to the end of the benefits conferred upon mankind by the use of the electric furnace, for without the great heat which it produces we should be deprived of our supply of that wonderful, light, and useful metal known as aluminium. Aluminium is the most plentiful of all metals, for it is the metallic base of clay, yet it had been until recently one of the most difficult to procure. Sixty years ago aluminium could only be got from its ores by a most difficult and expensive chemical process, and in those days its price was many times that of silver. At exhibitions you would see a little bar of aluminium shown under a glass case and labelled "Silver from clay." It was a curiosity—nothing else. Even so late as 1890 the amount of aluminium produced in the whole world was only forty tons, and its price was nine shillings and sixpence a pound. In 1900 the output was nearly six thousand tons, and the price had dropped to eighteenpence a pound. The change was due to two discoveries: the first, that of the electric furnace; the second, that out of all its different ores one called 'bauxite,' from Les Baux, near Arles in France, where it was first found, was that from which aluminium could be most easily extracted.

One of the most important of the works at which aluminium is extracted stands on the south shore of Loch Ness in Scotland, and is worked by water-power from the famous Falls of Foyers. The great Girard turbines work under a vertical head of 350 feet of water, and five thousand horse-power is employed day and night (so long as the water lasts) in the production of aluminium.



WELDING RAILS BY THE THERMIT PROCESS
G. Henry Lvison

The bauxite comes from the North of Ireland; the metal, as produced at Foyers, is 99.5 per cent. pure.

Aluminium is rapidly becoming the most valuable of all metals to man. Its most noticeable feature is, of course, its wonderful lightness. Bulk for bulk, it is only one-third the weight of cast-iron and less than one-fourth that of lead. It is so ductile that wires can be made of it less than one-hundredth of an inch in diameter, and so malleable that it can be hammered out into sheets $\frac{1}{40,000}$ of an inch in thickness. It is also a good conductor of electricity. As a substitute for iron in the manufacture of cooking utensils it is coming into very wide use, for it is an excellent conductor of heat, yet is not easily tarnished or affected by acids. It is easily cleaned, and has the great advantage over enamelled ware that it does not chip. For military canteens, or for travellers' or explorers' outfits, its lightness makes it invaluable. Nearly all the great firms which make such things as meat extracts, mineral waters, margarine, sweets, sugars, jams, and milk preparations use vessels made of aluminium. For optical and scientific instruments aluminium is used more and more every year. Motor-car manufacturers would be lost without this metal, for it is the ideal material for gear-cases and pistons. Various alloys, or mixtures, of the metal are used for motor-car bodies and the like. The framework of the modern airship is built entirely of aluminium alloys. One of the most valuable properties of this metal is its readiness to mix with others; and some of the alloys, while little heavier than the pure metal, are almost as strong as steel. Never a month goes by without some new use being found for this wonderful grey metal, and it might almost be said that an aluminium age is succeeding the age of iron and steel.

In addition to those substances already mentioned there are other productions of the electric furnace. One

is carbon bisulphide, which is formed by running melted sulphur over red-hot carbon, and another is phosphorus, of which the world's chemists are now using more than a thousand tons a year.

Time and again we notice how each step forward in the path of progress leads to new and unexpected discoveries. The use of the electric arc led to the mass production of aluminium; this metal in its turn has of late years become a cheap and convenient agent for the production of high temperatures. When it is powdered and mixed with the oxides of other metals the mixture burns so fiercely that the whole mass melts at a white heat, the aluminium combining with the oxygen of the oxide, while the other metal remains in the crucible in a pure state.

This new process, by which chromium, manganese, vanadium, and similar metals are easily produced from their oxides, has been given the name of aluminothermy. One of its most interesting developments has been the welding of iron and steel by means of thermit. This is simply a mixture of aluminium powder and ferric oxide, or iron rust. When this mixture is ignited in a crucible, the reaction is so violent that the temperature rises to 3000 degrees centigrade. The iron collects at the bottom of the crucible, and can be poured at once over any parts that need to be welded. Thus tram-rails can be joined after they have been laid in position. If a ship breaks her stern-post it is easy to repair it in dry dock and make it as good as new within a few days. Formerly the casting and fitting of a new stern-post would have taken many weeks.

There are plenty of other uses for thermit. You will have heard of the incendiary bombs that were dropped on London during the Great War. They produced such a heat that if one fell in the middle of the street the woodwork on each side was scorched. These bombs were filled with thermit.

CHAPTER XXVIII

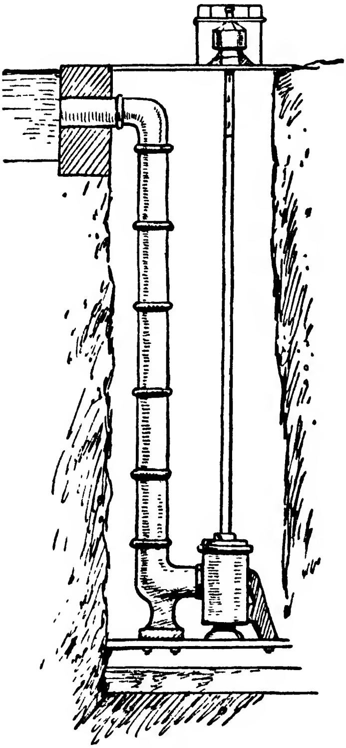
HARNESSING NATURE

Various Sources of Power—The Turbine and the Pelton Water-wheel—The Wasted Wind—Power from the Tides, and Direct Heat from the Sun.

IN Chapter XXVII I said something of the many valuable materials produced cheaply by the tremendous heat of the electric furnace. Now, while we can obtain electric power by burning coal or oil or gas, a far more economical method of producing it is from water-power. Coal represents the locked-up energy of the sunshine of former ages, but in order to use its mechanical energy it must be dug from the earth and baked or burned. Although the stocks of coal hidden in the bosom of the earth are very large, yet they are not endless; in England the shallow deposits have already been worked out and only the deeper ones are now available, and these are naturally more expensive to raise to the surface. Consequently, British coal is already twice its price of a few years ago, and tends to become still more costly.

Water-power differs from coal-power in that it can never be exhausted so long as rain falls upon the hills and snow upon the mountains, yet up to a comparatively recent date nearly all this wonderful supply of energy has been allowed to run to waste. Not quite all, for the power of falling water has been known to man for thousands of years, and in the East water-wheels have been used time out of mind for irrigation purposes. Later on, the water-wheel came into use in Europe for grinding corn, for running sawmills, and for other similar purposes, but no inventor of the time was able to solve

the problem of constructing a water-wheel suited to any but the most moderate power. So when steam-power came in, the first thing to be scrapped was the old water-wheel, and during the 18th century and most of the 19th no advance was made in the use of water-power.



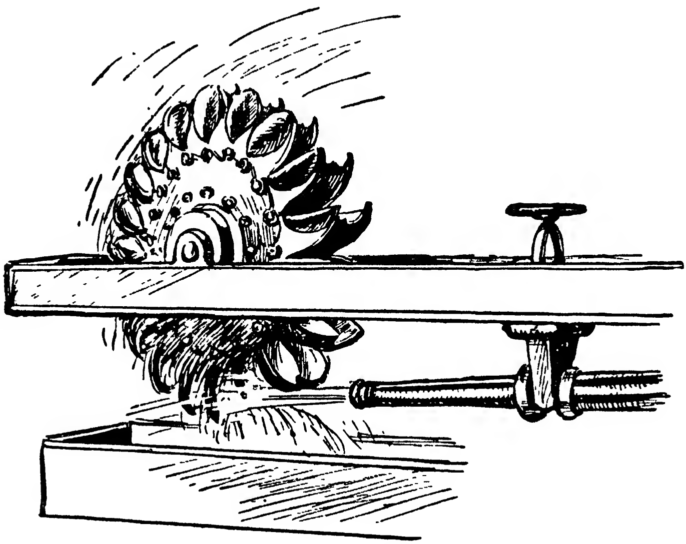
TURBINE AT NIAGARA

The causes which brought about the return to water-power were the inventions of new methods for making use of it, and of these the most important are the turbine and the Pelton water-wheel. The turbine was actually invented about the year 1801. Briefly speaking, it is a wheel with thin curved blades enclosed in a casing. The water falls through a conduit called 'the penstock,' and, entering at the circumference of the casing, is turned upon the blades by guides, and escapes in the centre. The movement of the blades rotates a shaft which communicates with a dynamo, as appears in the illustration.

There are many different modifications of the turbine according to the head and weight of water available. Turbines are made with vertical shafts which will work with a head or fall of only three feet, but the horizontal type is used with heads of water exceeding sixteen feet.

The Pelton water-wheel was invented by an American carpenter of that name. The water flows from a nozzle against the cup-like blades of the wheel, and so rotates it.

Many water-wheels of the old type—that is, of the sort you may see in the old-fashioned water-mill for grinding corn—were used in the early days of gold-mining in Western America. They were employed to obtain power for sluicing the gold-bearing soil from the faces of the cliffs. These old-fashioned wheels, of which many still



A PELTON WHEEL

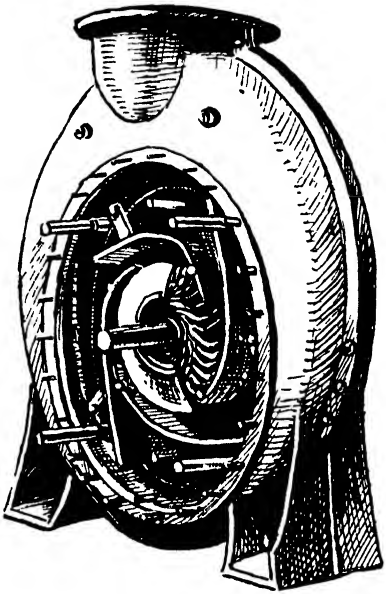
exist, have buckets or cups on the outer rim of the wheel into which the water pours from above, its weight causing the wheel to revolve.

The wheel which Pelton was repairing had gone a little crooked, and Pelton was sharp enough to notice that the jet of water coming from above and falling on one side of the buckets instead of into the middle did not splash and seemed to drive the wheel at increased speed.

The idea came to him to divide the buckets in the middle; and after making a wheel on these lines he found, just as he had expected, that it worked much better than

the older form. A glance at our illustration shows the Pelton wheel better than a page of explanation.

Let us consider just how water-power is used with the aid of the turbine—that is, a wheel with curved blades enclosed in a casing. As we all know, the Niagara River is the spout through which the surplus waters of Lake Erie flow into Lake Ontario. The fall at Niagara is 216 feet, and the quantity of water coming over is reckoned at 222,400 cubic feet a second, or nearly a cubic mile in one week. To put it from another point of view, the weight of water falling is twenty-two million tons an hour, or the equivalent of five million horse-power. The first turbines used at Niagara were massively constructed wheels of bronze, each 5 feet in diameter. They were set at the bottom of a 'wheel-pit' 140 feet long by 18 feet wide by 178 feet deep.



INTERIOR OF A DOUBLE-VORTEX TURBINE

The water is directed upon the blades by guides and is discharged at the centre The wheel is rotated by the endeavours of the water to escape.

The water is carried from the main river to the mouth of the wheel-pit by a canal 250 feet wide and 12 feet deep. Each turbine, of which there are ten, was built to give five thousand horse-power. In order to carry away the water after it had been used, a tunnel was cut one and one-third miles long through the solid rock. This tunnel is 19 feet wide and 21 feet high.

This, however, was only the first of a number of similar installations made on both sides of the Falls; and to-day

for over three hundred miles east and west, and more than a hundred miles north and south, electric power from Niagara works great factories, runs railways, lights towns, and does all the work which, in less favoured localities, requires the burning of millions of tons of coal.

America's water-power is enormous, and is being constantly developed. England has few such resources, but something is being done to make use of the considerable water-power available in the Highlands of Scotland. Italy, being a country with no natural supplies of coal or oil, is entirely dependent upon other sources of power, and is rapidly harnessing every available waterfall. Perhaps because she is so short of fuel, Italy is the first country in the world to make a serious attempt to use the internal heat of the earth.

At Larderello, forty miles south-west of Florence, is an area of two and a half square miles which, for thousands of years, has been avoided by the superstitious peasant. Here jets of steam issue from the earth with queer, whistling noises, and the air is heavy with the reek of sulphur. Some years ago Prince Conti determined to make use of this waste steam and put up an electric generator. It worked excellently, and to-day the towns of Florence and Siena are lighted by volcanic power. Generating plant is being built to increase the output to fifty-five thousand horse-power, and near Naples borings are being made with the object of installing similar plant, for here is another area which gives out steam.

There are but few places where steam is tapped close enough to the surface to be of use; but happily there is no part of the world where the wind does not blow, and next to water-power it is wind-power that is most likely to supply man's need for fresh sources of power.

Over continents and oceans mighty rivers of air sweep unceasingly; but we, living behind walls or in gardens sheltered by trees, are apt to forget these little-used forces.

A wind-engine is the most economical of all sources of power. A stationary wind-engine needs no crew; it turns itself to face the wind and reefs its own sails when the wind increases in force. It merely needs oiling occasionally, and for the rest looks after itself. What, then, is the disadvantage of this cheapest of servants? It is this: the wind does not always blow. This cessation is quite irregular, and the duration of a calm cannot be foretold. It may last an hour only or it may go on for a week. Yet if the wind is fickle it is not so treacherous as might be supposed. On an average there is always a working wind for half the year, and in open country three hundred feet above sea-level there is a wind of ten miles an hour or more for nearly three-quarters of the time.

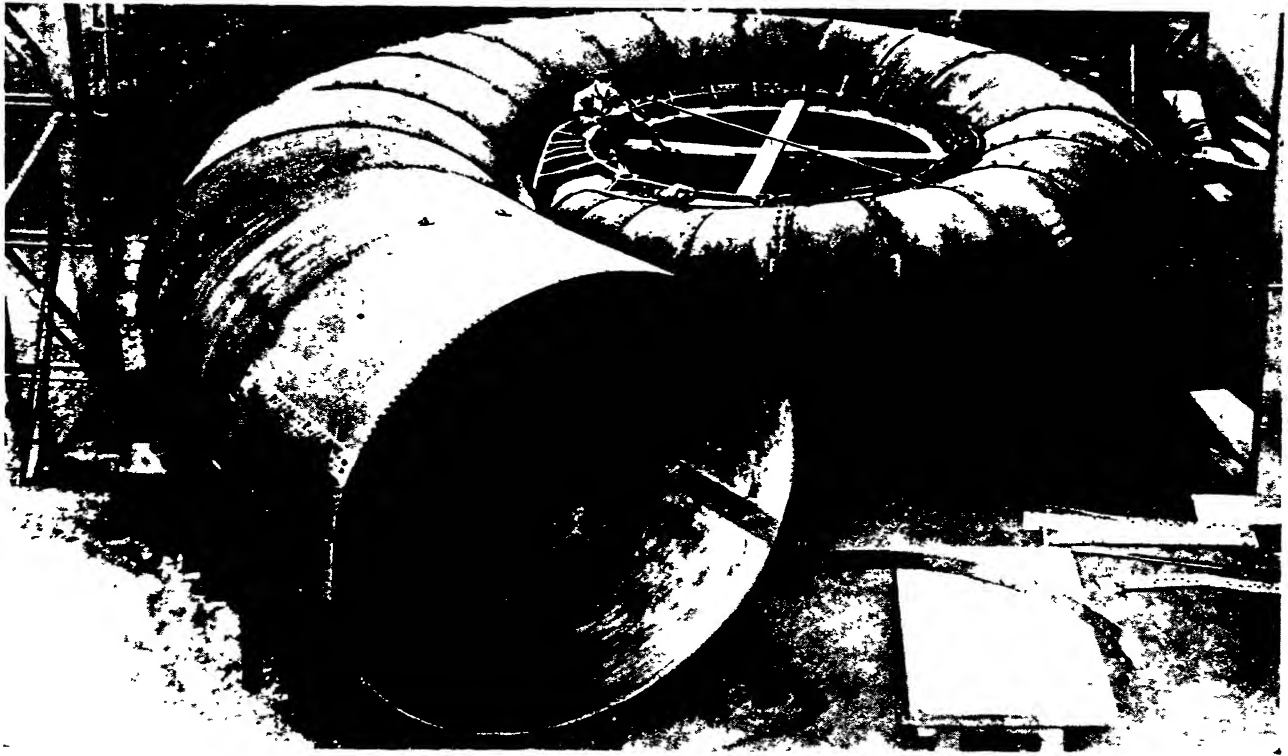
Of late years many improvements have been made in the windmill, and to-day a steel tower with a wheel of sixteen to twenty feet in diameter can be put up fairly cheaply and will do a surprising amount of work. It will pump water, drive a sawmill, churn, crush feed, mix manure, or run an electric-light plant. It will deliver daily ten thousand gallons of water to a height of one hundred feet, and will, at any rate, save the keep of a horse. In America an ever-increasing number of these small steel windmills are being set up, and the number now sold is not much less than ten thousand yearly.

These modern wind-engines differ very widely from the old radial-armed windmill with its wooden shutter or canvas sails. In those old-time windmills the sails had to be pushed into the wind by means of a long tiller arm at the base, but this was replaced by the revolving head, which automatically brought the mill into the wind. In the centre of the sails was mounted a governor which acted directly on the divisions of the sails, opening or closing them as required. In the new type of steel-tower wind-engine the control is effected by the use of a revolving head with a rudder or tail vane, which, if

MOULDS BEING FILLED WITH HOT STEEL AT PITTSBURG STEEL WORKS

Photo Keystone View Co.

[*Chapter XXVII*]



A MONSTER TURBINE
Photo Keystone View Co

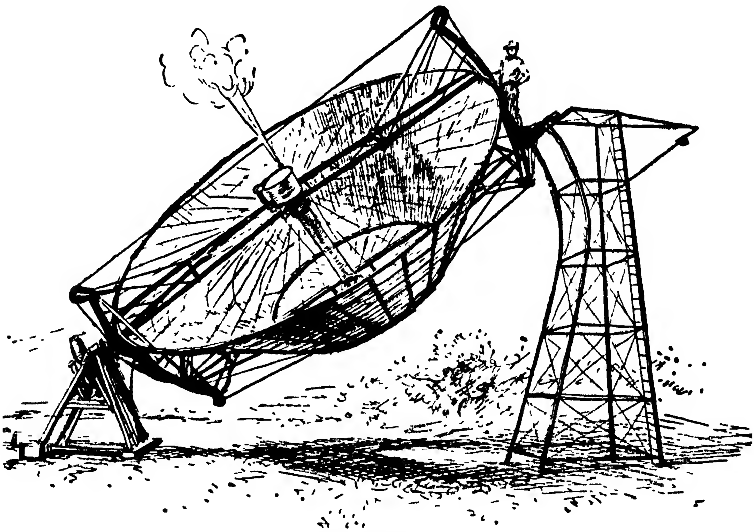
the wind blows too hard, turns the wheel more or less away from it. A new form of windmill was invented by Major Bilau in 1924, which is said to have advantages over any of the older types. Whereas all windmills hitherto have faced the wind, and all subsidiary apparatus, including the vane, have been behind, Bilau's wheel is on the side of the tower remote from the wind, so that the wind leaving the machine suffers no disturbances. It is free to exert its full 'suction' effect. That is the first step toward getting the maximum power out of the wind. He uses only four 'wings' in his wheel, instead of six or eight as customary in old types, but the most striking difference is that Bilau's wind-wings are shaped on scientific principles. They are, in fact, exactly the same as aeroplane wings, and for precisely the same purpose—to obtain the maximum 'suction' effect. Bilau also provides what would appear to be a perfect automatic regulator.

So it looks as though the world was at the beginning of a new effort to make more use of the neglected wind. Professor Fessenden, a distinguished Canadian, lecturing before the British Association, stated that if windmills were put up along the English cliffs there would be easily obtained enough electric power to run all the railways and manufactories in the country.

Another form of power which is at present even more neglected than that from wind is tide-power. There are, it is true, great obstacles in the way of the use of tidal force in most countries, for the rise and fall are not sufficient to give great power without enormous expense. There are, however, certain localities, such as the mouth of the River Severn and the Bay of Fundy on the Nova Scotian coast, where it would be feasible to harness these mighty forces.

In the Bay of Fundy the tide rises and falls no less than forty feet twice a day. Here the tidal race pours out to

sea through a narrow gap not more than three miles wide, and careful calculation proves that through this gap two hundred million horse-power runs to waste every day in the year. To utilize this gigantic force would mean the expenditure of millions; but the power obtained would be so tremendous, and therefore so cheap, that it is safe to predict that it will be done.



THE SOLAR MOTOR AT SOUTH PASADENA

The French Government is to undertake a tidal-power scheme at Aber Wrach in the *département* of Finistère in Brittany. It is proposed to erect a barrage 164 yards long and four groups of turbines which will be driven both by the flood- and ebb-tides. A minimum of 1600 and a maximum of 3200 horse-power will be obtainable.

The last source of power which I shall mention is that obtainable from direct solar heat. At South Pasadena in California a ten-horse-power boiler has been working for some years by steam which is raised entirely by sun-heat. The apparatus consists of a cone lined with 1700

mirrors, so arranged as to reflect upon a steel tube containing about a hundred gallons of water, and placed in the centre of the cone. The cone, driven by clockwork, follows the movement of the sun. The boiler can be used for eight hours on every clear day, and it takes no more than an hour to get up steam, after which the engine works steadily until sunset. It is capable of pumping about fourteen hundred gallons of water in a minute. The cost compares favourably with coal-heated or electrically driven engines. At Meadi, a suburb of Cairo, a complete sun-power plant was set up for working an irrigation plant; but the temperature obtained was so much higher than expected that the zinc boilers, which were similar to those used in California, would not stand the strain. It appears that in any tropical country where fuel costs more than ten shillings a ton sun-power could be used with advantage.

CHAPTER XXIX

WHAT MACHINERY DOES FOR MAN

The Triumph of the Inventor—Machinery *versus* Man—The Hopelessness of Hand Labour—How Inventors have made Life Easier for Man.

I REMEMBER once hearing a lecturer speak of 'fatal' inventions. He was not, however, referring to big guns or poison gas, but merely to the fact that all progress is bought at a cost. Inventions have, of course, played havoc with old institutions and forced mankind from old beaten paths into new ways of doing things, and there are among us some who are so conservative in their minds that they are full of regret for the old ways. There are, for instance, folk who tell you that there never was or will be any finer method of travelling than in a light carriage behind a pair of high-stepping horses, and others who declare that there is no comparison between a great three-masted ship heeling under a full press of canvas and an ugly tramp steamer driving through the waves with a long trail of sooty smoke hanging behind her.

There is a great deal of truth in such remarks, for certainly a pair of well-bred trotting horses are much more beautiful to look at than the finest of modern motor cars, while of all things that man ever made there is certainly nothing more exquisite than a big sailing-ship running free before a fair wind.

Yet, on the other hand, the car will carry you farther and faster than all the horses in the world, and with greater comfort as well as speed; while the steamer drives along with almost the certainty of a railway train, irrespective of storm or calm. And so we may well be

grateful for the immense advantages which the present generation owes to the inventor and to those who are responsible for the marvellous mechanical devices which are a part of modern civilization.

In order that you or I may live we must have a sufficiency of food and of clothing. We must also have a roof to cover us, books from which to learn, and means for moving about from one place to another. Does it ever occur to you to compare our lot in these respects with those of our great-grandparents? Only the other day I was talking to an old peasant woman who, although she has lived all her life within fifty miles of London, has never seen the world's greatest city. Do you realize that, a hundred years ago, it was only the well-off people who ever travelled, and that in any English village not three per cent. of the people had ever visited any large town or, if it was inland, seen the sea? Most people lived the lives of vegetables, and were, in consequence, intensely ignorant and full of foolish superstitions.

Since the population was small, and farming was the principal industry, food was fairly plentiful, but clothes, and especially boots, were very dear and bad. There were no umbrellas or waterproofs, and if you had to go out in the rain you got soaked. The houses of the poor were entirely without many of those things which to-day are necessities. There was no proper water-supply or drainage. There were no cooking-ranges or carpets, there were hardly any books, while a single newspaper passed from hand to hand until it was worn out.

As for travelling, the rich drove in their carriages, the middle class went by stage-coach or rode on horseback; but for the poor the only alternative to walking was one of those slow, heavy waggons which averaged something less than three miles an hour, or, with luck, a canal boat.

Almost every article in common use was hand-made; and while hand-made goods were, and are, strong and

durable, they all took so long a time to make that they were naturally expensive. Take, for instance, such a necessity as a pair of boots. To make even the cheapest and commonest pair of men's boots took fifteen and a half hours of steady work. That is why such boots cost twenty to twenty-five shillings a pair at a time when the wages of the man who made them were only about threepence an hour. The invention of bootmaking machinery enabled a man to make ten pairs of boots in the time previously taken to make one, with the result that boots can now be sold for less money, while at the same time working men are paid much better wages.

Turn to farm implements, and we find that at the beginning of the 19th century it took two hundred working hours to make fifty pitchforks. By 1865 the same number of pitchforks were made by machinery in twelve hours. Not a cast-iron plough existed in the year 1800; the farmer's plough was made of wood covered with a thin sheet of iron; seeds were scattered by hand, and the only way of keeping down the weeds was by hoe. The farmer used the scythe or sickle for cutting his grain and the flail for threshing it. Wheat was ground between two stones in a water- or wind-mill. There are parts of the world, such as Russia, where these old-fashioned conditions still exist; but in most countries either steam-ploughs or tractor-cultivators are used, and every operation, from sowing the seed to reaping and threshing, is done by machinery. In Western America a harvester is used of which the cutting bar is thirty-five feet wide; it is drawn by an engine of fifty horse-power. Behind the harvester is trailed a thresher, into which the stalks of grain pass after being cut. The grain is separated from the chaff by means of a fan, and is automatically loaded into sacks, while the straw passes into a receptacle at the back of the machine and is 'dumped' at regular intervals. The capacity of this machine is from a

thousand to fifteen hundred sacks of grain a day, all cut, threshed, cleaned, and sacked; and the result of this marvellous invention, or rather series of inventions, is that the work of seven men is sufficient to grow enough wheat and thresh and grind it into flour to provide bread for a thousand persons.

When we come to the making of bread we find that here again the inventor has been busy saving labour. Some years ago there was shown at the Bakers' and Confectioners' Exhibition at the Agricultural Hall in London an electrically worked machine, weighing nearly two hundred tons, which was capable of making and baking two thousand four hundred loaves an hour. Eight men standing at the levers of this machine are able to do all the work, and do it quite easily, but not one of them touches or handles the flour or dough. The flour is placed in a large compartment in which just sufficient water is added for the kneading of the dough. The dough, mixed by machinery, is tilted into a sort of wagon, and runs down into the 'proving' room, where it lies for four hours and ferments.

When it has risen sufficiently, it is carried to a dividing machine, which cuts it into pieces; and these pieces, traversing an endless band, are delivered to the moulder, which shapes them into loaves. They then drop upon an electrically propelled rack, and are swept into a gigantic oven, which bakes them to perfection in the brief space of forty-two minutes. Were it not for the machinery which many clever brains have invented, a loaf of white bread would to-day cost two or three times its present price.

Biscuits are made, like bread, by machinery. If you visit a biscuit factory you will see all the materials mixed by machinery. They are never once touched by the human hand, and the way in which they are baked is very interesting. The biscuits, lying on a sort of endless band

made of wire gauze, go into a very long oven, pass slowly through it without stopping, and come out at the other end, perfectly baked.

Nearly all our food, especially the tinned and bottled goods which form so large a part of it, are prepared by machinery. All our drinks are bottled by automatic machinery. There is a very cleverly made machine which seizes empty bottles, clutches each by the neck, and fills them at the rate of twenty-four thousand a day. Another machine corks bottles at the rate of three thousand an hour. Consider what an army of men it would take to do such work by hand labour!

In the old days all washing of clothes had to be done by hand, and the laundresses had to work very hard for very little money. But visit a modern steam laundry, and you will see machinery that will wash and finish collars and cuffs at the rate of two thousand an hour; that will wash two hundred shirts in the same time, and gloss and iron them at the rate of one every minute. There are even machines for marking linen, one of which does the work of six women.

Our ancestors were forced to light their houses with candles, for there was no other illuminant to be had. We still use candles; but these, instead of being made by hand by the old and very slow process of dipping, are moulded, and one machine, which a boy can attend to, makes seven thousand candles in an eight-hour day. The time saved by machinery in the making of matches is even more startling than that economized in the manufacture of candles, for the match-cutting machine cuts 6375 matches in the same space of time that a man could shape three matches by hand.

A hundred years ago every nail used by the carpenter was hand-made, and whole towns were engaged in nail-making—men, women, and children. It was not only cruelly hard work, but was one of the worst paid of all

A DAIMLER TRACTOR DRAWING A FIVE-FURROW PLOUGH

[See p. 282]

THE STEAM NAVVY AT WORK

While the hand-labourer starts digging from the surface downward, the scoop of the steam shovel attacks the trench from the bottom upward.

industries, and the nail-makers lived always on the edge of starvation. Then the inventor set his brain to work, with the result that we now have a machine which makes nails at the rate of a thousand a minute. The cruel old trade of nail-making by hand is now dead, and nails are cheaper and better than ever they used to be.

Bricks are still moulded by hand in some small, out-of-the-way places, but the hand-made brick cannot compete with the machine-made. The machine will mould thirty thousand bricks in ten hours, whereas the most skilled workman could not make even a tenth of the number in the same time. Bricks bring to mind clay and the digging of canals and harbours. Once upon a time all this sort of work had to be done by hand labour, but then came the invention of the steam navvy. This machine will do the work of a giant thirty feet high, armed with a seventeen-foot shovel. Even more wonderful is the dipper-dredge so much used in cleaning mud out of harbours or deepening rivers and canals. Such a dredge has a crew of six men, and, on three tons of coal, digs from 1500 to 2000 tons of mud or slush in one working day. It can manœuvre itself in any direction, dig foundations, lay concrete blocks, raise wrecks, lift boulders, and, as a proud owner once said, do almost everything except vote.

Formerly all painting was done by a brush held in a man's hand and dipped at intervals into a paint-pot. Small wonder, then, that painting was a slow and costly business. For industrial purposes the inventor found a better way, and to-day paint is sprayed on to the surface to be covered when it is a large one. For painting the hull of a battleship or the outside of a railway carriage, for example, this wonderfully time-saving method is in almost universal use. The paint mixed to the consistency of cream is held in a small steel tank connected with a

reservoir containing compressed air. It comes out of a brass nozzle in a sort of fan-spray, and all the operator has to do is to wave the nozzle to and fro. In this way one man can do the work of seven armed with brushes and paint-pots.

In Chapter XV some description has been given of the beginnings of printing by steam and of the wonders of type-setting by machinery. Almost more uncanny than the Linotype or Monotype machines is a machine for folding, wrapping, and addressing magazines, which was invented by Mr George Livingston Richards, an American publisher. This auto-mailing machine occupies a small room, yet does the work of a hundred people. Piles of newly printed magazines are fed in on one side of it, and a moment later come out upon the far side rolled, wrapped, and addressed, rushing along an endless band and falling gently into their appointed sacks. The machine handles the magazines at the rate of several thousands an hour. Equally ingenious is a smaller piece of mechanism, about the size of a typewriter, which 'licks' stamps and puts them on the packets at the rate of eight thousand an hour, and, into the bargain, counts every stamp used.

We also have at our disposal the most marvellous calculating machines, each of which can dispose of problems in arithmetic more swiftly than could half a dozen trained clerks, while the results are always correct. All the great banks use calculating machines, and thereby save the labour of extra clerks. One of these machines can take any money sum and almost instantly show its equivalent in the currency of another country calculated to the existing rate of exchange; another can give the exact interest upon any sum of money for any length of time at any desired rate.

Other interesting developments are: electric typewriters which are set to work by the merest touch on the keys, typewriters which will write in a bound book,

automatic cashiers which pay out and give change at a touch on a button, loud-speaking telephones which dispense with a receiver, and cheque-writers which work faster than a pen and make forgery impossible. The use of these and similar inventions results in business undertakings being managed with far greater ease, power, and profit than formerly. Principals and clerks alike find their work simplified by the skill of the inventor, and every year sees fresh improvements in these methods.

There is no branch of human endeavour in which modern machinery is not able to save time and trouble. It is often complained that British coal-pits are ill-provided with modern machinery as compared with those in the United States. The nature of this disadvantage is plain when we are told that it takes a man a hundred and seventy-one hours to cut fifty tons of coal by hand, whereas the same work can be done by one man with the aid of machinery in one-third of the time. In quarrying, the saving of time by the use of machinery is still more startling; for whereas to drill by hand six two-inch holes twelve feet deep in hard blue rock occupies a hundred and eighty hours, the same work performed by machine takes only eight hours.

The more rapidly work can be done, the more leisure there will be for the worker; and we may look forward with some confidence to the time when, instead of an eight-hour day, four hours will be sufficient to supply every one with all that he or she may need.